NASA's Earth Science and YOU

Kent Shiffer - Project Manager
Earth Science Project Office
Ames Research Center

ESPO

Pleasantville the Movie

NASA's 2011 Mission Statement

Vision:

To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.

Mission:

Drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth

ESPO
NASA

Overview Topics

Global need for "Earth System" understanding

NASA's relationship to Earth Science

- Satellites (Orbital assets)
- Airborne (Suborbital assets)
- Ground measurements (Terrestrial assets)

Earth Science Project Office -Ames Research Center

- Current projects around the globe


Executive Office of the President
National Science and Technology Council
Chair: President, Vice Chair: OSTP Director
Members: President's Cabinet
Committee on Environment,
Natural Resources and Sustainability
Co-Chairs: OSTP, NOAA, EPA
Subcommittee on Global Change Research
13 Agencies and Departments NOAA, DOI,
NASA, DOE, USDA, NSF, EPA, HHS, DOT, DOS,
DOD, SI, USAID

ESPO

US Global Change Research Program

- USGCRP's Vision and Mission:

Vision:

- A nation, globally engaged and guided by science, meeting the challenges of climate and global change

Mission:

- To build a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication, and decision support


NASA
Science Mission Directorate
(SMD)
Earth Science Overview
ESPO
NASA

NASA's relationship to Earth Science

NASA's Earth Observing System (EOS) science in support of the

USGCRP

USGCRP Focus Areas

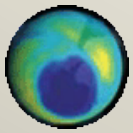
United States Global Change Research Program

1. Improving our knowledge of Earth's past and present climate variability and change
2. Improving our understanding of natural and human forces of climate change
3. Improving our capability to model and predict future conditions and impacts
4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change
5. Providing climate information and decision support tools
6. Climate Change Communication and Education

http://downloads.globalchange.gov/ocp/ocp2011/ocp2011.pdf

ESPO NASA

NASA - HQ Program Focus Areas



- **Atmospheric Composition**
  - Atmospheric Chemistry Modeling and Analysis Program
  - Radiation Sciences Program
  - Tropospheric Chemistry Program
  - Upper Atmosphere Research Program

Carbon Cycle and Ecosystems

Ocean Biology and Biogeochemistry Program

Weather and Forecasting

Atmospheric Dynamics and Remote Sensing Program

Water and Energy Cycles

Cryospheric Program

Airborne Science

Suborbital Sciences Program

NASA's relationship to Earth Science

NASA's Earth Observing System (EOS)

The Nation now has a system of spacecraft with the ability to characterize the current state of the Earth system. In the years ahead, NASA's fleet will evolve into constellations of smart satellites that can be reconfigured based on the changing needs of science and technology. From there we envision an intelligent and integrated observation network composed of sensors deployed in vantage points from the subsurface to deep space. This ***"sensorweb"*** will provide on-demand data and analysis to a wide range of end users in a timely and cost-effective manner. This observation system will have many practical benefits for scientific research, national policymaking, and economic growth.

http://science.nasa.gov/earth-science/missions/

ESPO NASA

NASA's relationship to Earth Science

Current NASA Satellite's in orbit

NASA presently has 13 on-orbit satellite missions: the Activity Cavity Radiometer Irradiance Monitor SATellite (**ACRIMSAT**), **Aqua, Aura**, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (**CALIPSO**), the Cloud Satellite (**CloudSat**), the Earth Observer (**EO**), the Gravity Recovery and Climate Experiment (**GRACE**), **Jason**, **Landsat-7**, the Ocean Surface Topography Mission (**OSTM**), the Solar Radiation and Climate Experiment (**SORCE**), T**erra**, and the Tropical Rainfall Measuring Mission (**TRMM**).

On 24 February 2009, NASA's Orbiting Carbon Observatory (OCO) satellite did not reach orbit altitude when the launch vehicle malfunctioned. On 11 October 2009 and 23 November 2009, respectively, the Ice, Cloud, and land Elevation Satellite (ICESat) and Quick Scatterometer (QuikSCAT) satellites ceased their primary geophysical missions after many years of extended service.

http://downloads.globalchange.gov/ocp/ocp2011/ocp2011.pdf

ESPO NASA

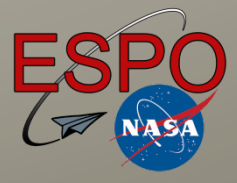
NASA's relationship to Earth Science

NASA Satellite Development

NASA has seven missions in development for launch between 2010 and 2015. Five missions (Aquarius, Glory, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), the Landsat Data Continuity Mission (LDCM), and Global Precipitation Measurement (GPM)) are foundational missions, which the Decadal Survey49 assumed would be precursors to Decadal Survey missions. Two missions, Soil Moisture Active-Passive (SMAP) and ICESat-2, are Tier 1 Decadal Survey missions.

The Decadal Survey is the principal determinant of the priorities of NASA's Earth Science satellite missions beyond those currently in development.

http://downloads.globalchange.gov/ocp/ocp2011/ocp2011.pdf



NASA Earth Science Animation

Current NASA Earth Science Satellite Operations

Earth ACRIMSAT ACRIMSAT is the latest in a series of long-term solar-monitoring missions, utilizing the proven Active Cavity Radiometer Irradiance Monitor III (ACRIM III) instrument. - Mission Complete 2005

Earth Aqua Aqua will obtain a set of precise atmosphere and oceans measurements to understand their role in Earth's climate and its variations. - Operating

Earth Aura The Aura satellite hosts a suite of scientific instruments designed to make the most comprehensive measurements ever undertaken of atmospheric trace gases. Operating

Earth CALIPSO The CALIPSO satellite was developed to help scientists answer significant questions and provide new information about the effects of clouds and aerosols (airborne particles) on changes in the Earth's climate. - Operating

Earth CloudSat CloudSat uses advanced radar to "slice" through clouds to see their vertical structure, providing a completely new observational capability from space. Operating

Earth Landsat 7 Landsat 7 systematically provides well-calibrated, multispectral, moderate resolution, substantially cloud-free, Sun-lit digital images of the Earth's continental and coastal areas with global coverage on a seasonal basis. It covers the United States every 16 days. - Operating

Earth NOAA-N NOAA-N
Polar-orbiting platform to support the environmental monitoring instruments for imaging and measurement of the Earth's atmosphere, its surface, and cloud cover. - Operating

Earth OSTM OSTM measures sea surface height to an accuracy of < 3.3 cm every ten days. - Operating

Earth Earth Observing-1 (NMP) The NMP EO-1 mission is an advanced land-imaging mission that will demonstrate new instruments and spacecraft systems. - Operating

Earth GOES I - **M** The GOES I-M satellites are the primary element of U.S. weather monitoring and forecast operations and are a key component of NOAA's National Weather Service operations and modernization program. - Operating

Earth GRACE The primary goal of the GRACE mission is to accurately map variations in the Earth's gravity field over its 5-year lifetime. - Operating

Earth Jason-1 Jason is an oceanography mission to monitor global ocean circulation, improve global climate predictions, and monitor events such as El Nino conditions and ocean eddies. - Operating

ESPO
NASA

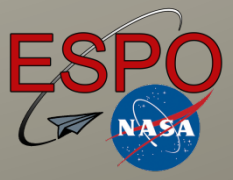
Earth SeaStar (SeaWiFS) The SeaStar satellite carries the SeaWiFS instrument which is designed to monitor the color of the world's oceans. - Operating

Earth SeaWinds (ADEOS II) The SeaWinds scatterometer is a specialized microwave radar that measures near-surface wind velocity (both speed and direction) under all weather and cloud conditions over Earth's oceans. - Operating

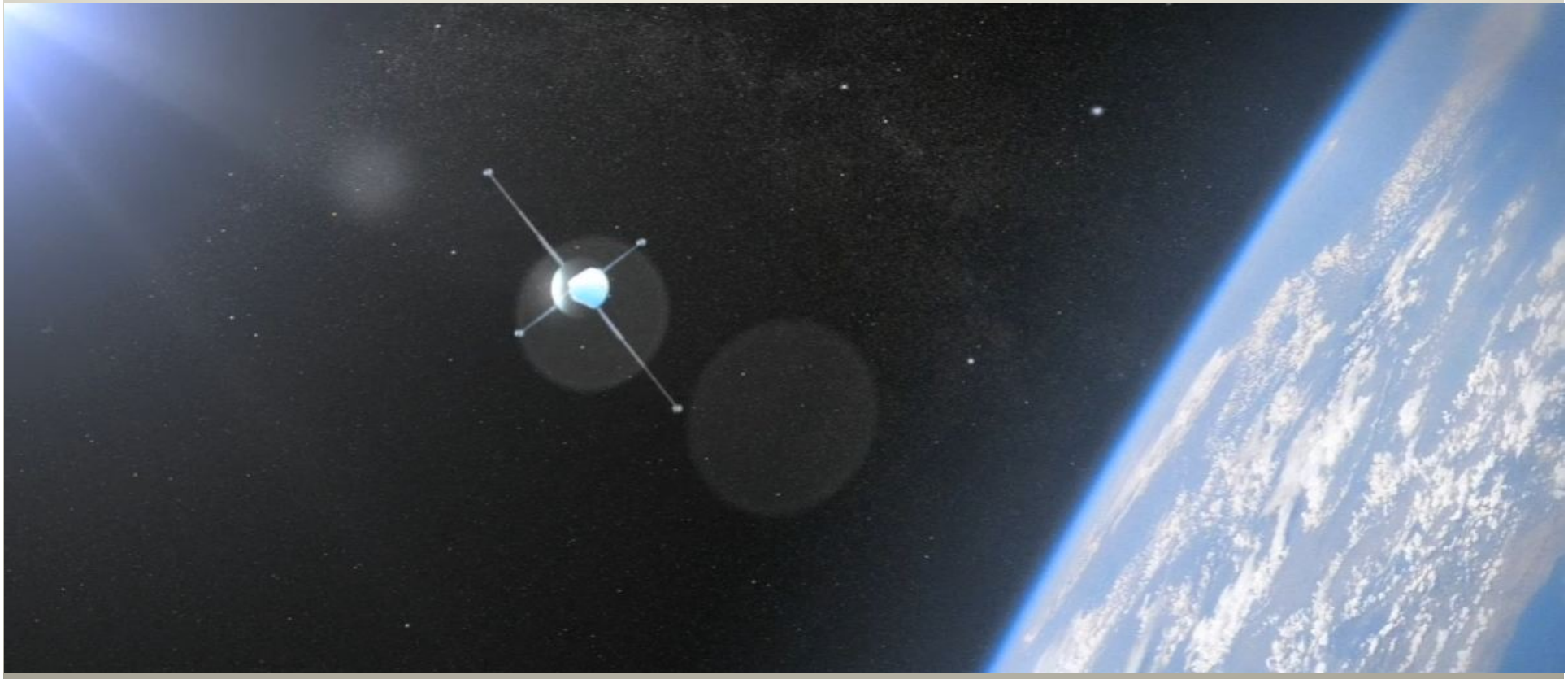
Earth SORCE SORCE is a NASA-sponsored satellite mission that will provide state-of-the-art measurements of incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation. - Operating

Earth Terra Terra (formerly EOS AM-1) is the flagship satellite of NASA's Earth observing systems. Terra is the first EOS (Earth Observing System) platform and provides global data on the state of the atmosphere, land, and oceans, as well as their interactions ... -Operating

Earth TRMM TRMM is a joint mission between NASA and the National Space Development Agency (NASDA) of Japan. TRMM is particularly devoted to determining rainfall in the tropics and subtropics of the Earth. These regions make up about two thirds of the ... Operating

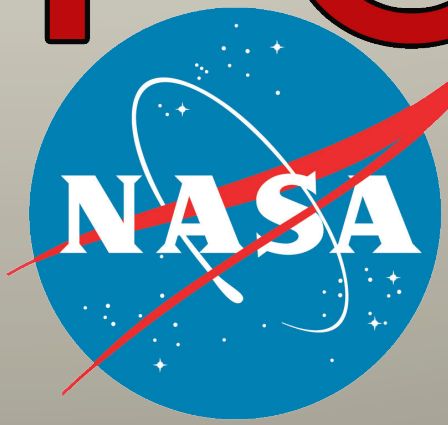


Warming World



Earth Science Project Office

ESPO



NASA Earth Science
Airborne (Suborbital) Experiments
http://www.espo.nasa.gov/

Earth ATTREX Stratospheric water vapor has large impacts on the earth's climate and energy budget. Future changes in stratospheric humidity and ozone concentration in response to changing climate are significant climate feedbacks.

Development

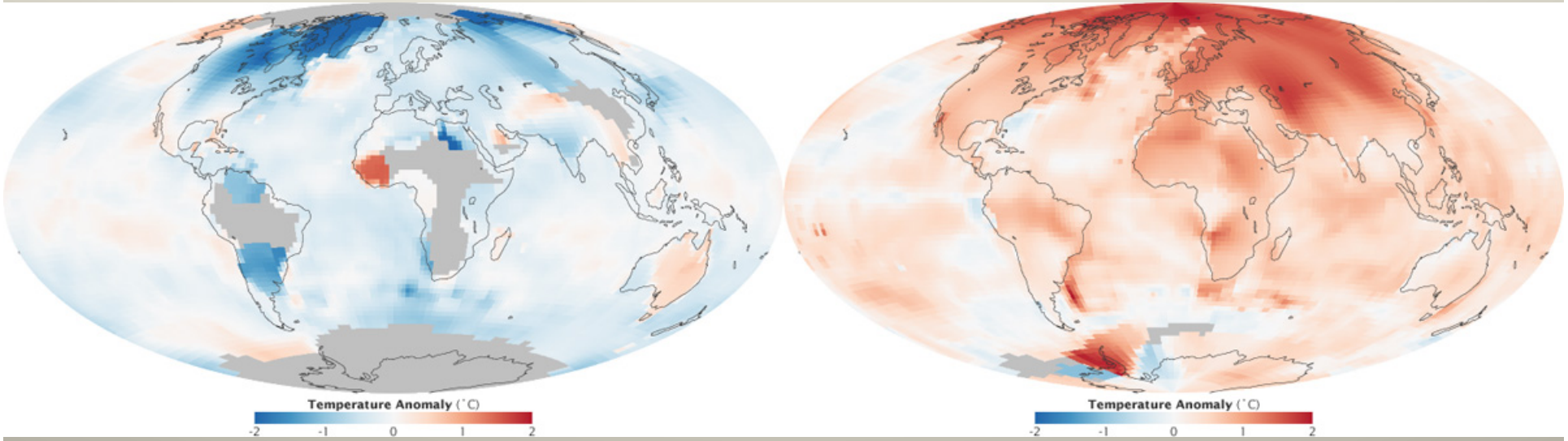
Earth HS3 The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission specifically targeted to investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin. HS3 is motivated by hypotheses related to the relative roles of the large-scale environment and storm-scale internal processes.

Development

Earth Operation Ice Bridge Operation Ice Bridge is a six-year airborne campaign designed to capture geophysical measurements of changes in polar ice sheets and sea ice during a gap in the space-based observations of ICESat and ICESat II.

Operating

NASA Earth Science



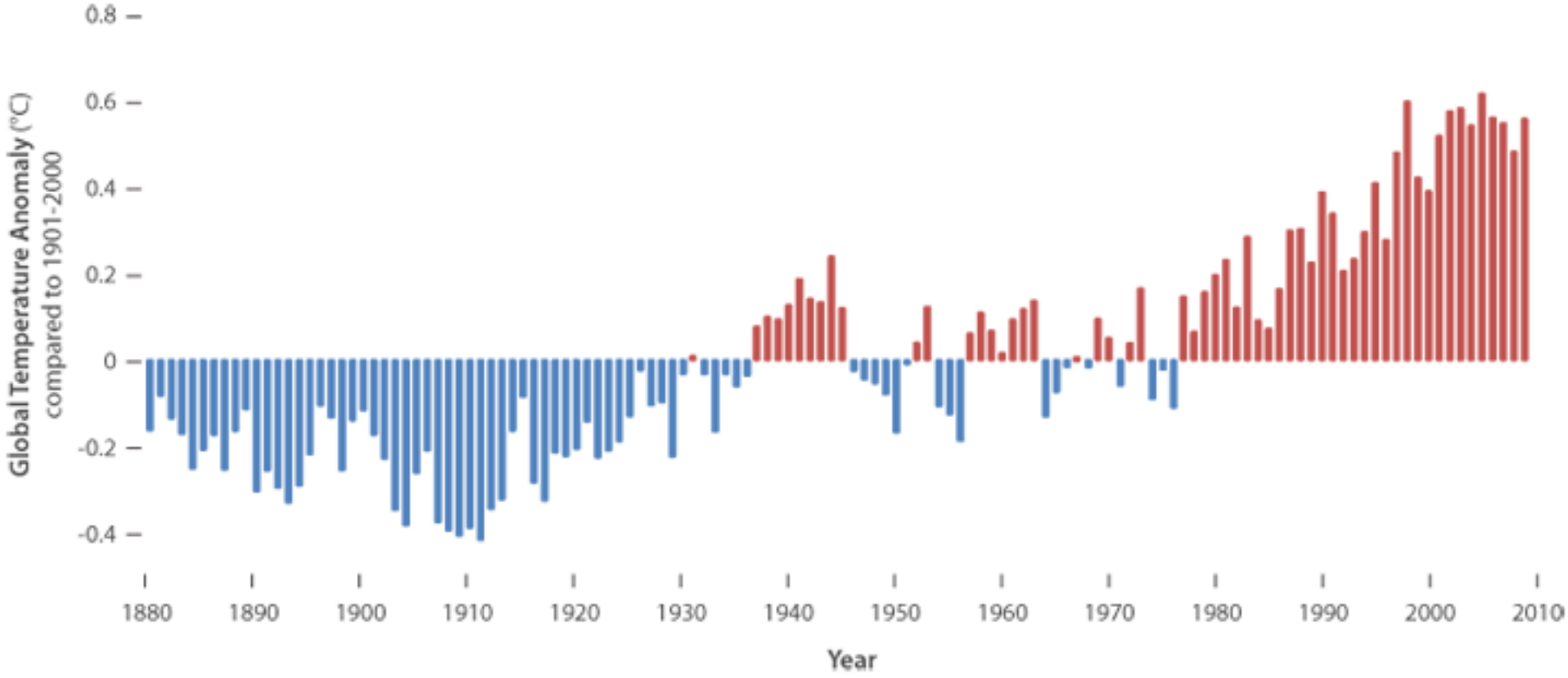
A CENTURY OF WARMING

Global temperature changes. Left: 1880-89. Right: 2000-09. These maps compare temperatures in each region of the world to what they were from 1951 to 1980. NASA's Goddard Institute for Space Studies conducted the analysis using ship-based and satellite observations of sea-surface temperature, and data from Antarctic research stations and 6,300 meteorological stations around the world. Earth's average surface temperature has increased by about 0.7 °C (1.3 °F) since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15 to 0.20 °C per decade

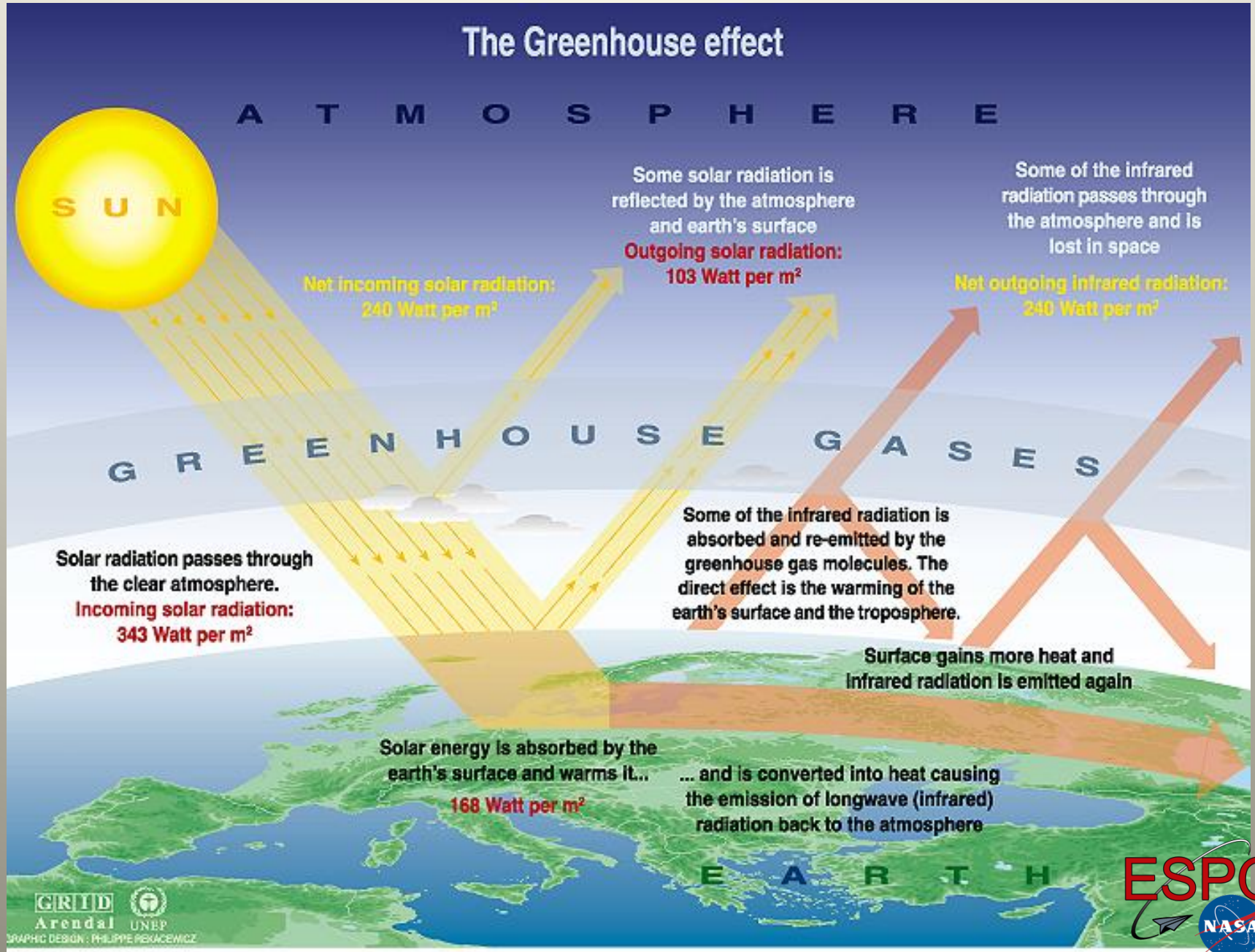
NASA GISS. Courtesy of the NASA Earth Observatory and Mike Carlowicz.

ESPO
NASA

Earth's Temperature Trend

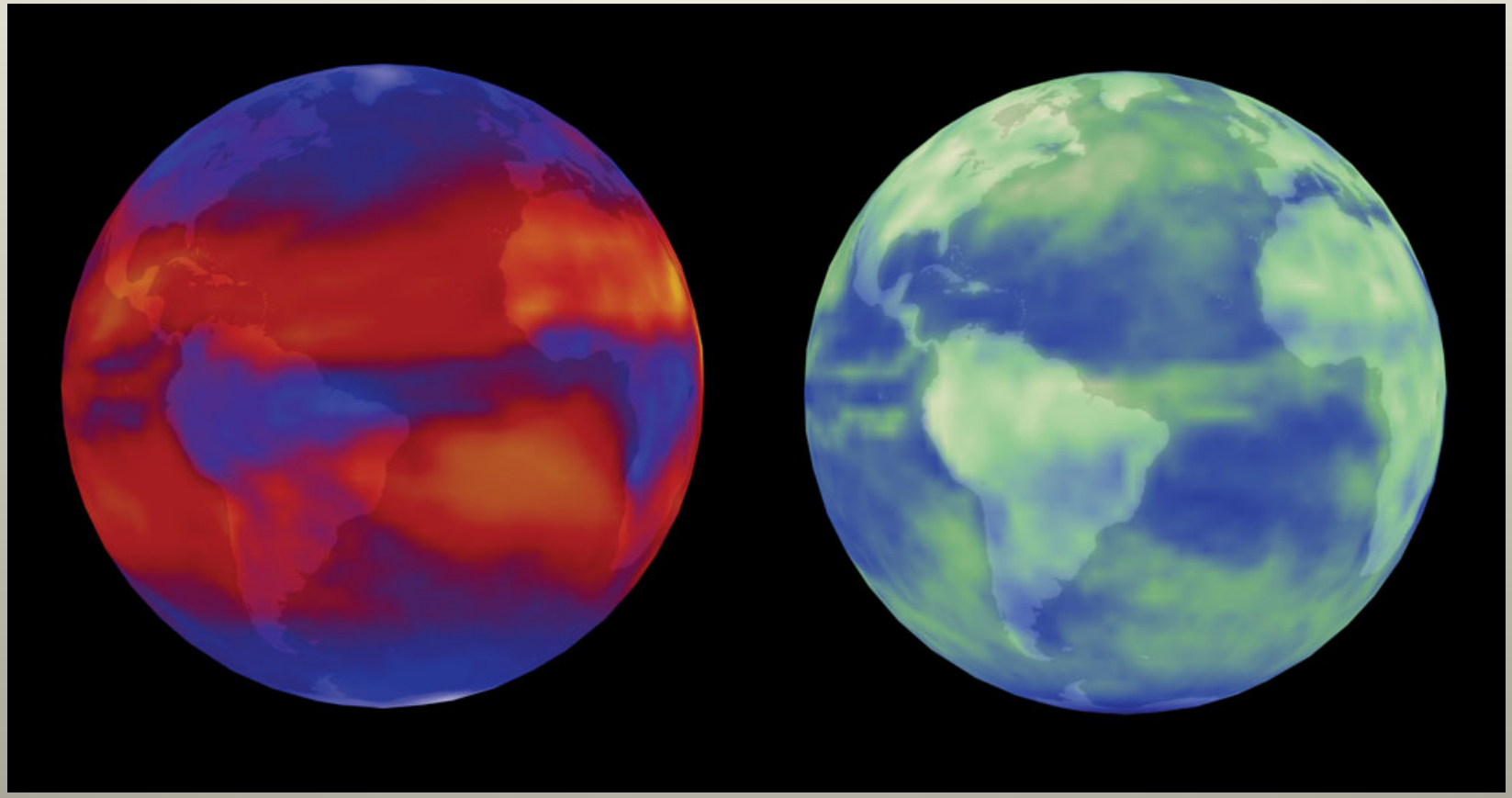


Human Contribution=
Population Growth +
Increased Consumption



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

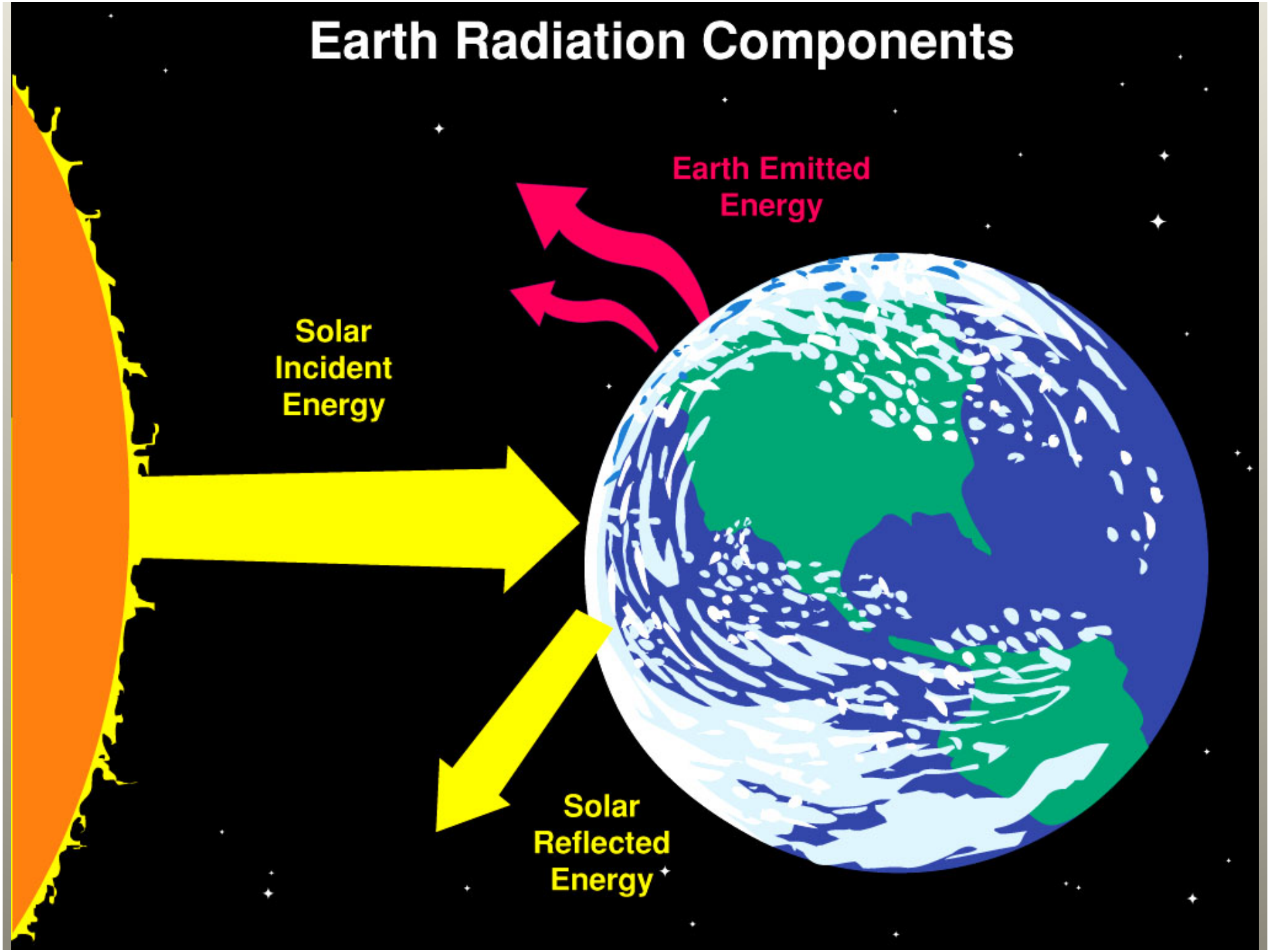
Earth Radiation



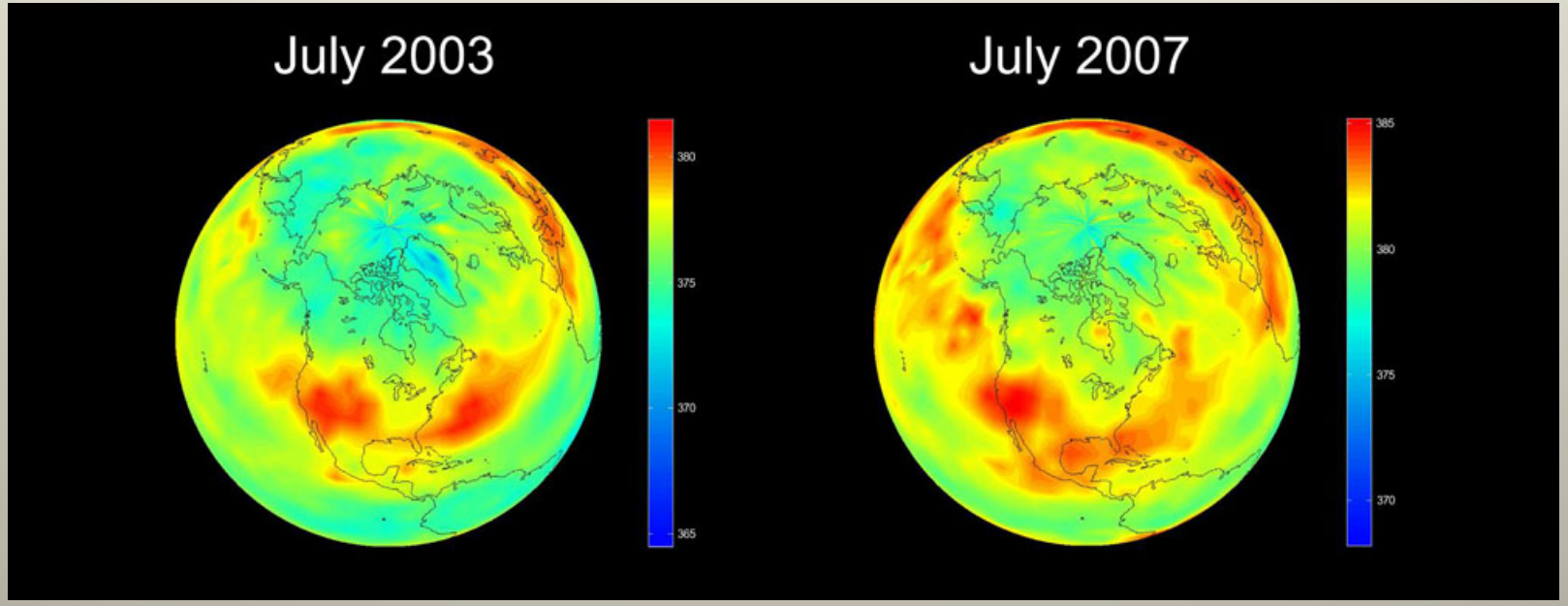
HOT ROCK

Left: April 2001; Heat given off by the Earth's surface and atmosphere and pumped out into space. Right: April 2001; Sunlight reflected back out to space by the oceans, land, clouds and aerosols. For scientists to properly understand climate change, they have to determine what drives changes within the Earth's radiation balance. These images, taken by NASA's CERES (Clouds and the Earth's Radiant Energy System) experiment, are helping to do that.

Data courtesy of the Atmospheric Sciences Data Center and the CERES Science Team at NASA Langley Research Center.
Images courtesy of Tom Bridgman, NASA Goddard Space Flight Center Scientific Visualization Studio


Earth Radiation Components
Earth Emitted Energy
Solar Incident Energy
Solar Reflected Energy

Earth's Changing Atmospheric Chemistry Human Contribution



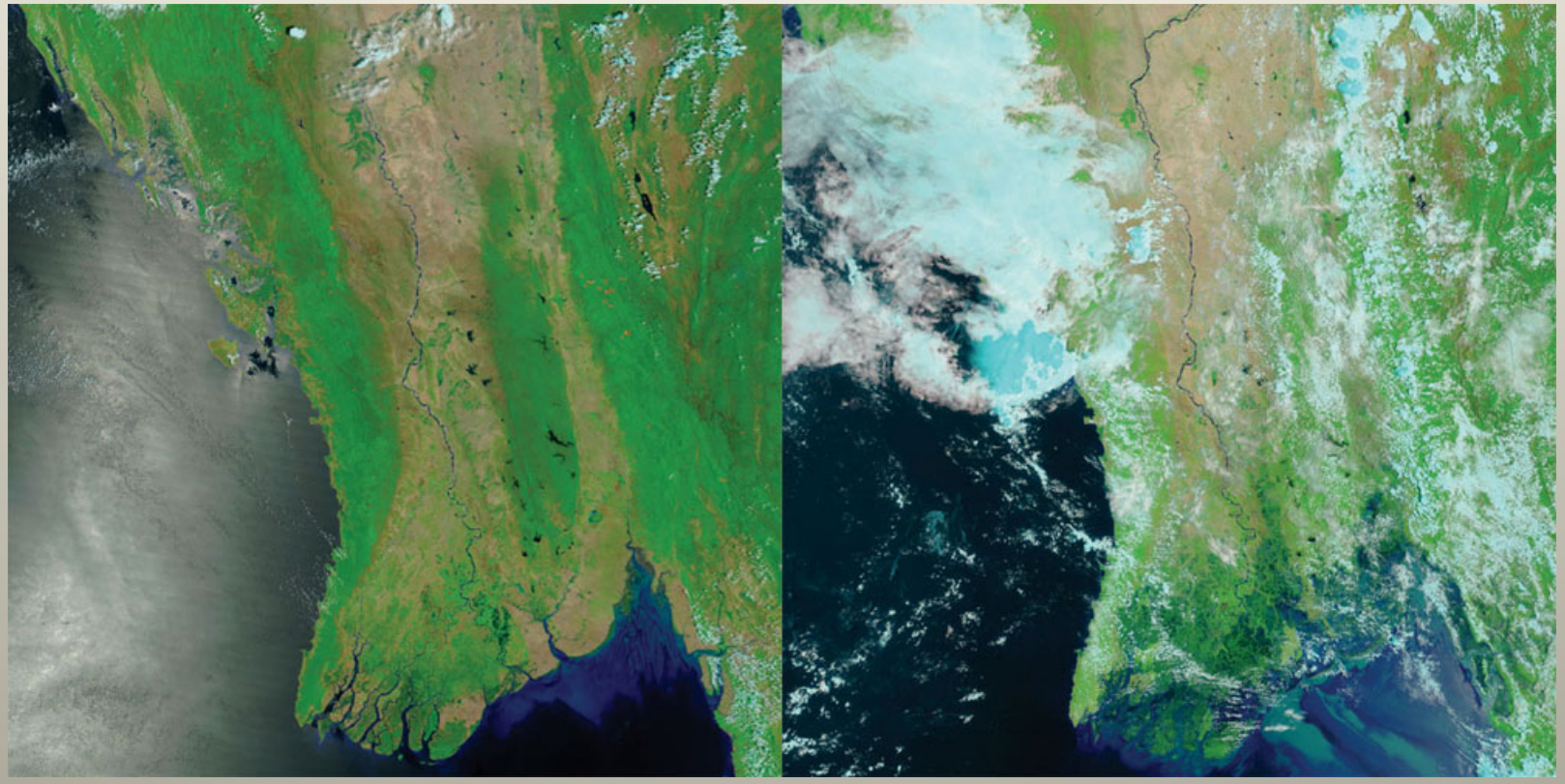
CARBON COUNTER

Carbon dioxide levels in our atmosphere are rising. Left: July 2003. Right: July 2007. Both images show the spreading of carbon dioxide around the globe as it follows large-scale patterns of circulation in the atmosphere. The color codes in these two pictures are different in order to account for the carbon dioxide increase from 2003 to 2007. If the color bar for 2003 were to be used for 2007, the resulting 2007 map would be saturated with reddish colors, and the fine structure of the distribution of carbon dioxide obscured

Images from the Atmospheric Infrared Sounder (AIRS) instrument onboard NASA's Aqua spacecraft. Credit: NASA/JPL

ESPO NASA

Earth's Atmosphere Changes the Coastline

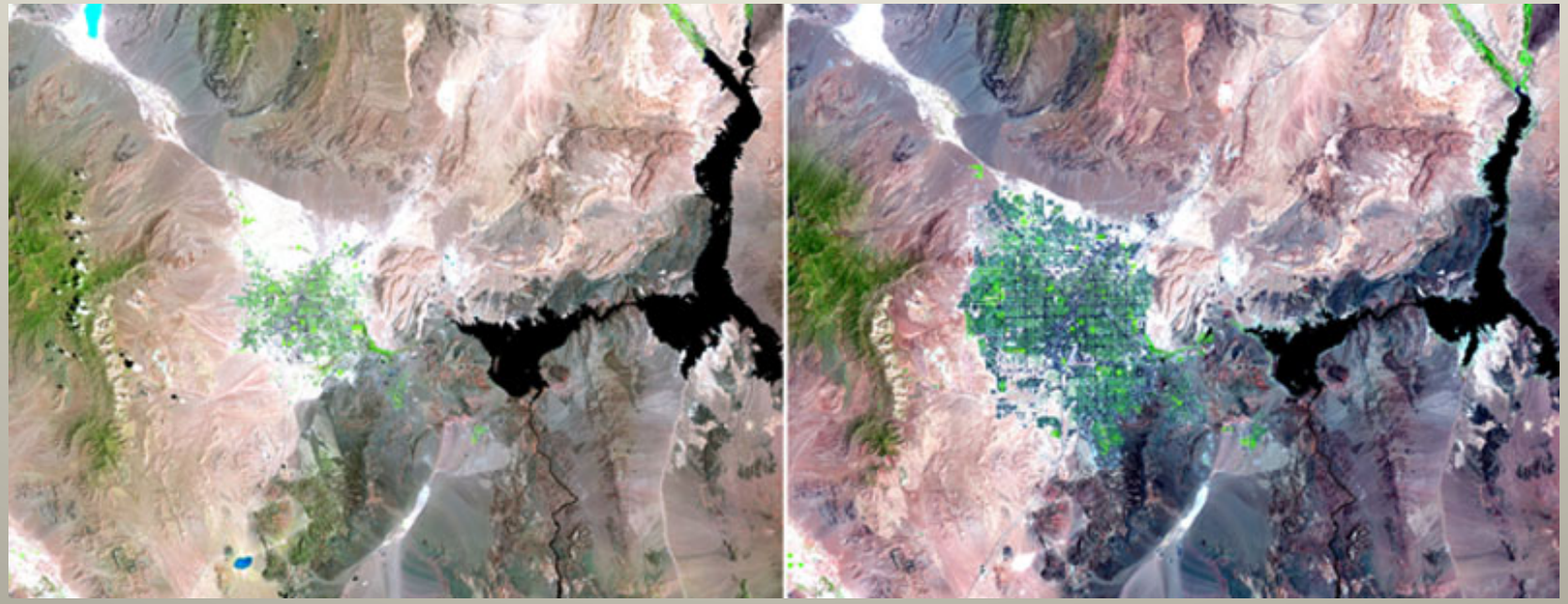


On May 2, 2008, Cyclone Nargis caused the worst natural disaster in the history of Burma (also known as Myanmar). Left: April 15, 2008. Right: May 5, 2008. Over 130,000 people were killed and, according to United Nations estimates, 1.5 million people were severely affected. More than $10 billion of damage was done. One of the things that made Nargis so deadly was the way in which it intensified so quickly before making landfall — from a category-1 to a category-4 tropical cyclone in just 24 hours.

Images taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Credit: NASA's Earth Observatory

ESPO NASA

Earth's Urban Growth



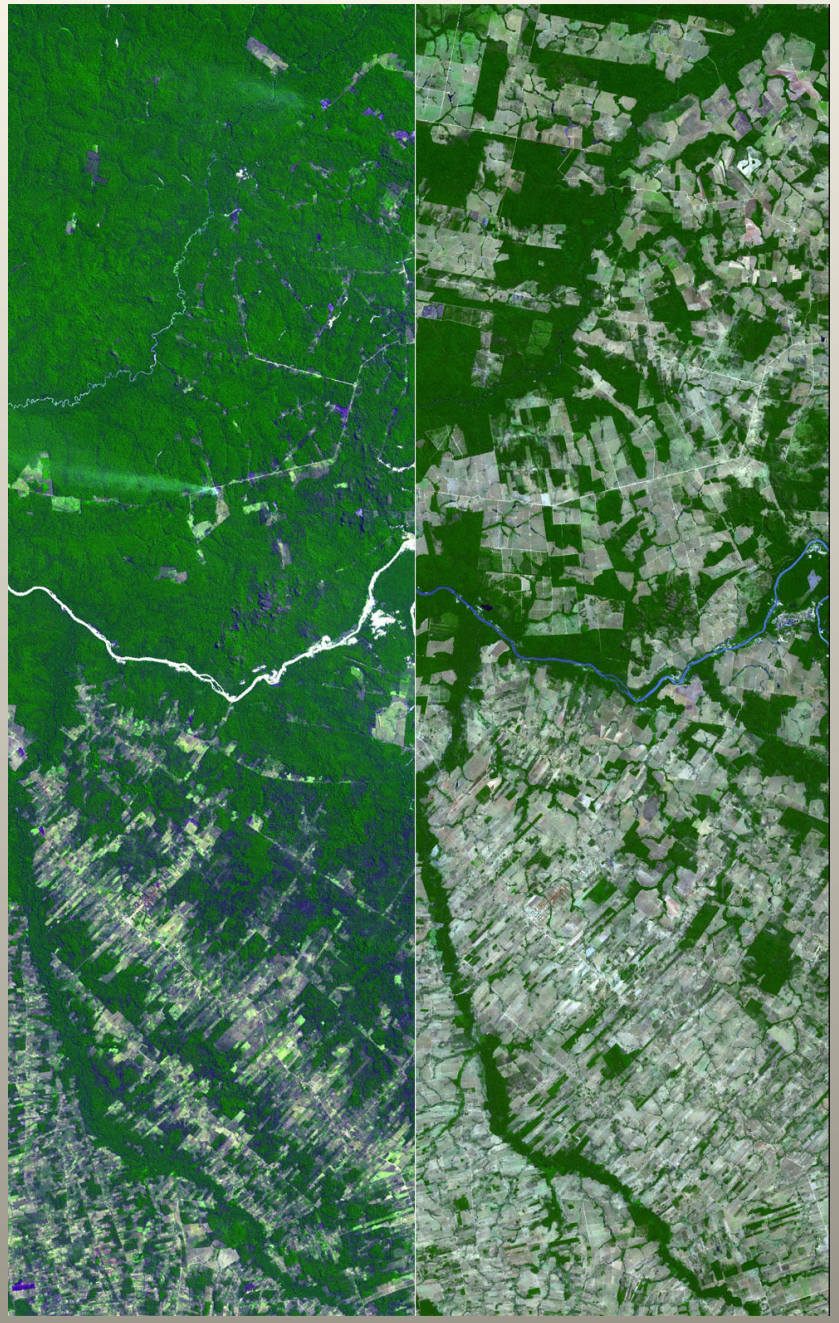
LAS VEGAS BOOM

Growth in the desert. Left: 1984. Right: 2007. These images show the increasing urban sprawl of Las Vegas, Nevada, and the shrinking of Lake Mead on the border of Nevada and Arizona. Rapid growth in Las Vegas has led to increased demand for water resources, while below-average rainfall has decreased the water levels in Lake Mead, which is the source of 90 percent of southern Nevada's water

Images taken by the Landsat-5 satellite. Credit: NASA/USGS.

ESPO NASA

Earth's Changing Land Use



1992 image acquired by the Landsat satellite (NASA/USGS).
2006 image acquired on July 28 by ASTER mission.
Credit: NASA/GSFC/ METI/ERSDAC/JAROS and the U.S./Japan ASTER science team.

MATO GROSSO, BRAZIL

The Mato Grosso state in southwest Brazil. Left: 1992. Right: 2006. In the Brazilian Amazon, deforestation has been proceeding at a rate of about 20,000 square kilometers per year. In 2006, the image shows over 80 percent of the rainforest gone, cleared for pastureland by commercial and speculative interests.

ESPO NASA

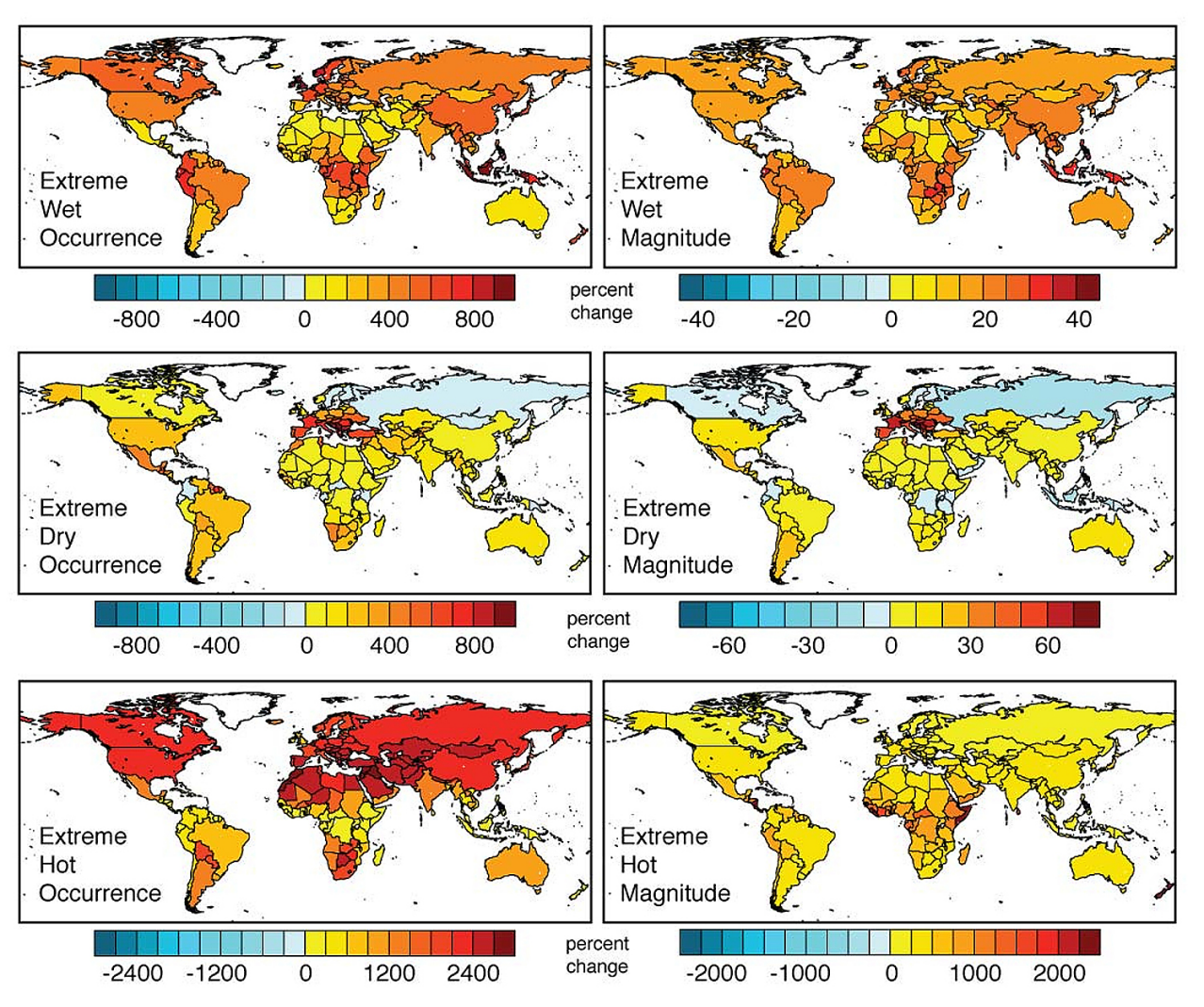
Helheim Glacier Retreat
Greenland

Left: May 12, 2001. Middle: July 7, 2003. Right: June 19, 2005.

Along the margin of the Greenland Ice Sheet, outlet glaciers flow as icy rivers through fjords and out to sea. These pictures show a fjord in which Helheim glacier (on the left) is crumbling into large and small icebergs (light blue, on the right). The glacier outlet ("calving front") held steady from the 1970s until about 2001, then began to retreat towards its source about 7.5 kilometers (4.7 miles) between 2001 and 2005. The glacier's flow to the sea has also sped up

NASA images created by Jesse Allen, Earth Observatory, using data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite.
Courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and the U.S./Japan ASTER Science Team

ESPO NASA



These maps show projected changes in frequency and magnitude of climate extremes. A Purdue team found that the occurrence and magnitude of what are currently the 30-year-maximum values for wet, dry and hot extremes are projected to substantially increase for much of the world. (Diffenbaugh lab image)

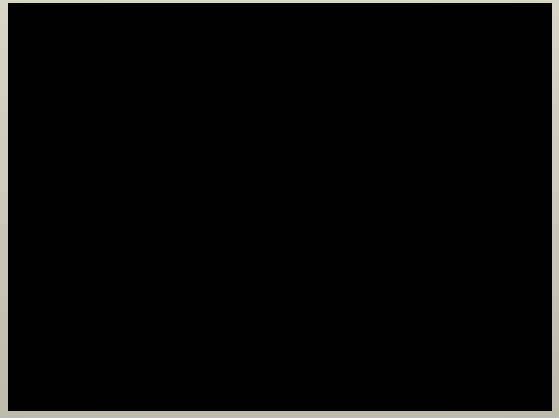
http://news.uns.purdue.edu/images/+2009/climatechange-maps.jpg

Operation IceBridge Overview

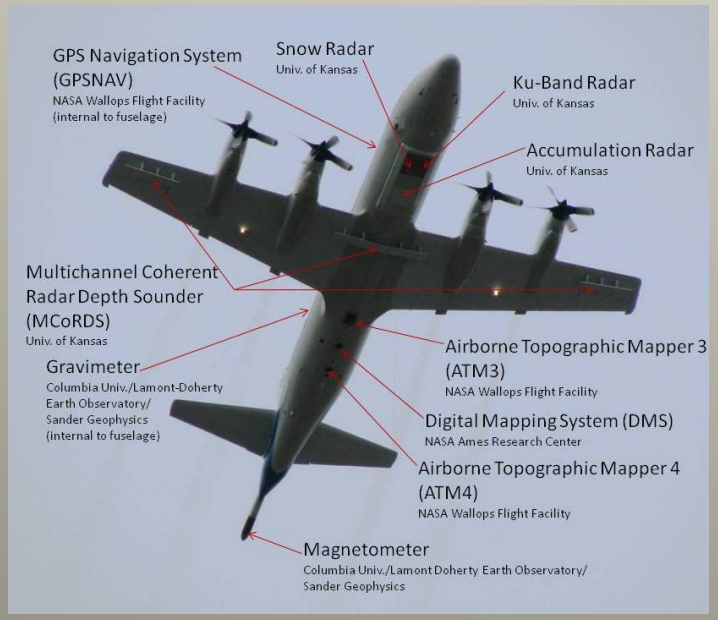
OIB Overview Video

Tour of the Cryosphere

Sea ice is frozen seawater floating on the surface of the ocean.
Some sea ice is semi-permanent, persisting from year to year, and some is seasonal, melting and refreezing from season to season. The sea ice cover reaches its minimum extent at the end of each summer and the remaining ice is called the perennial ice cover.

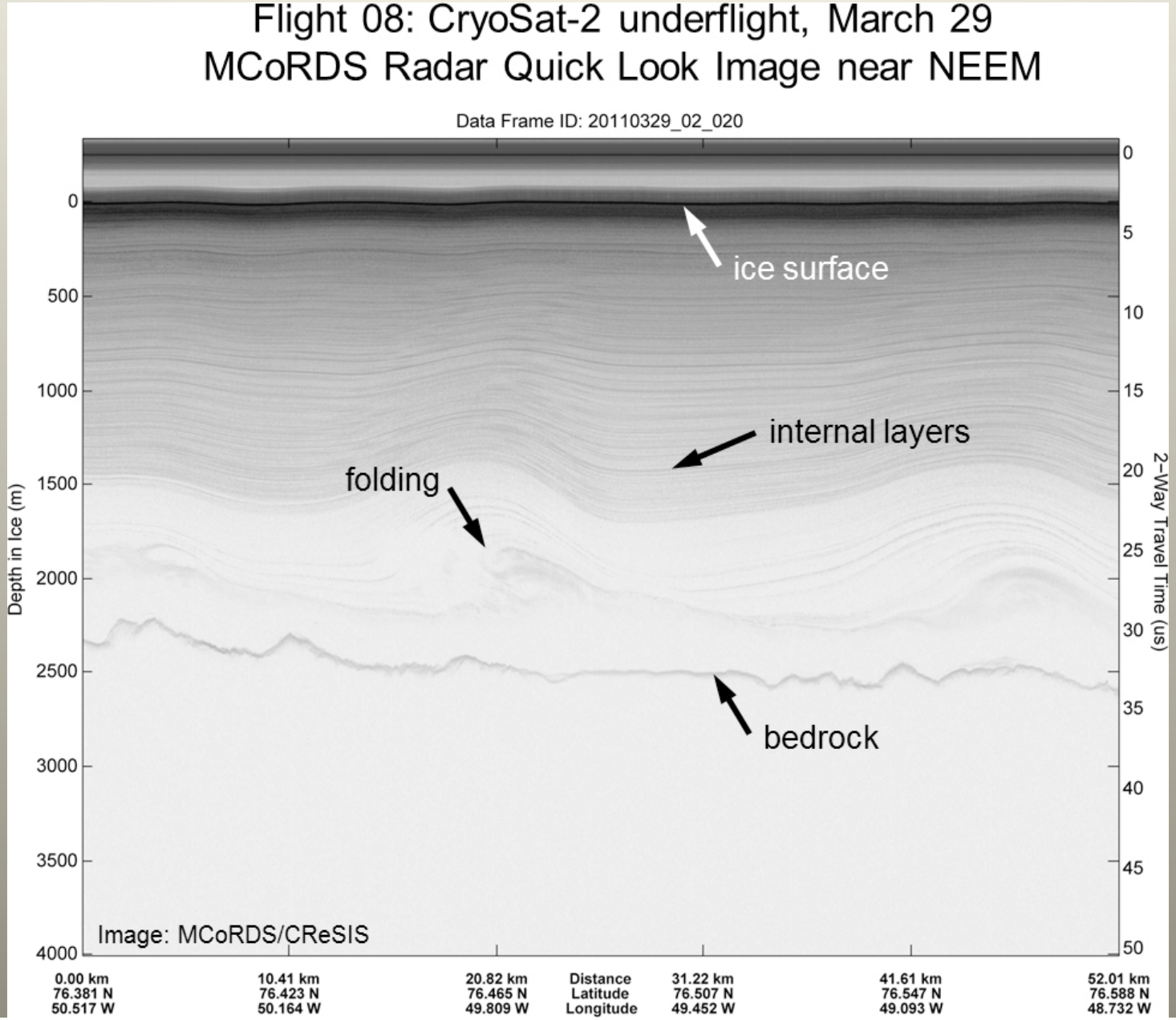


Operation IceBridge

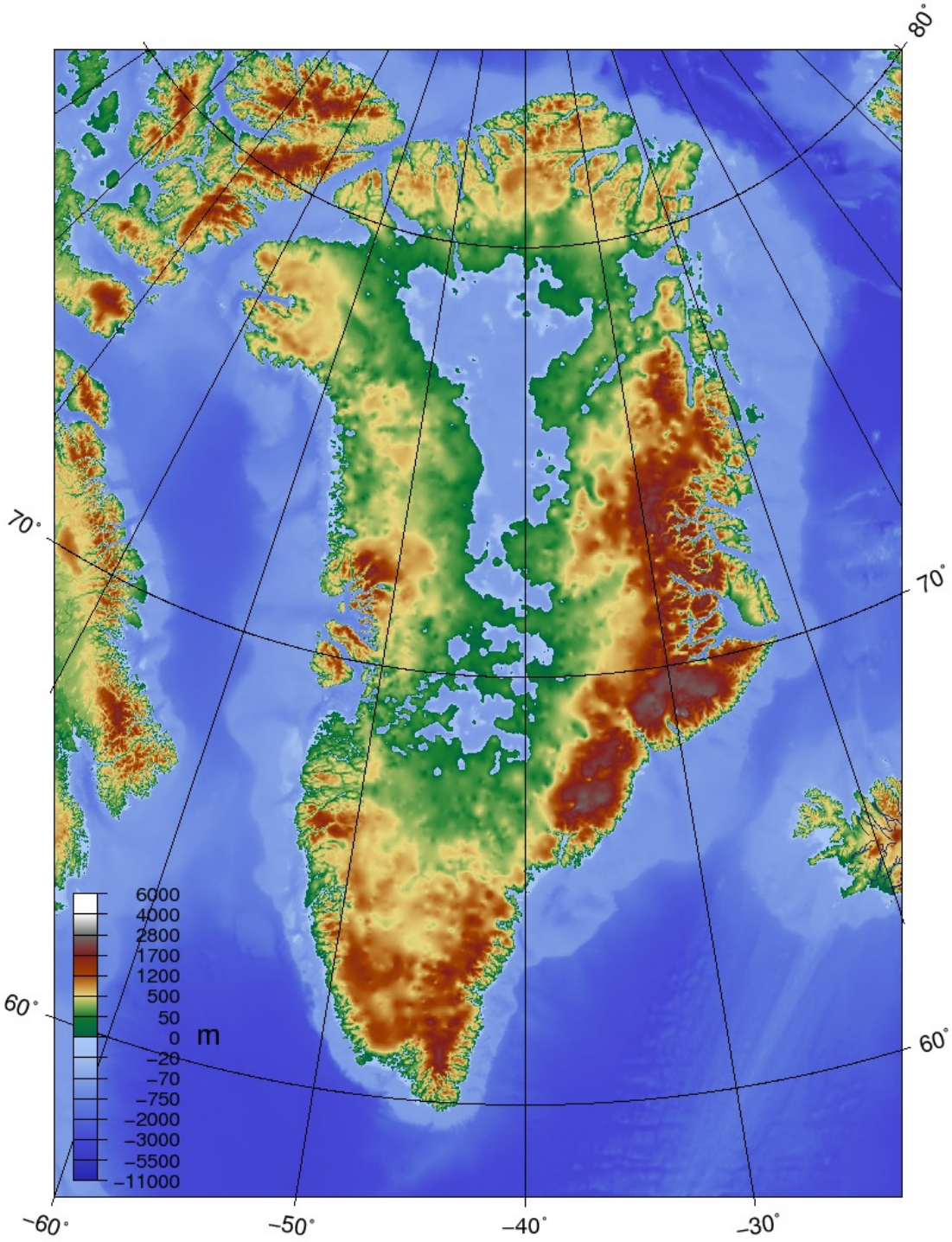


ESPO
NASA

Ice Penetrating Radar - Greenland



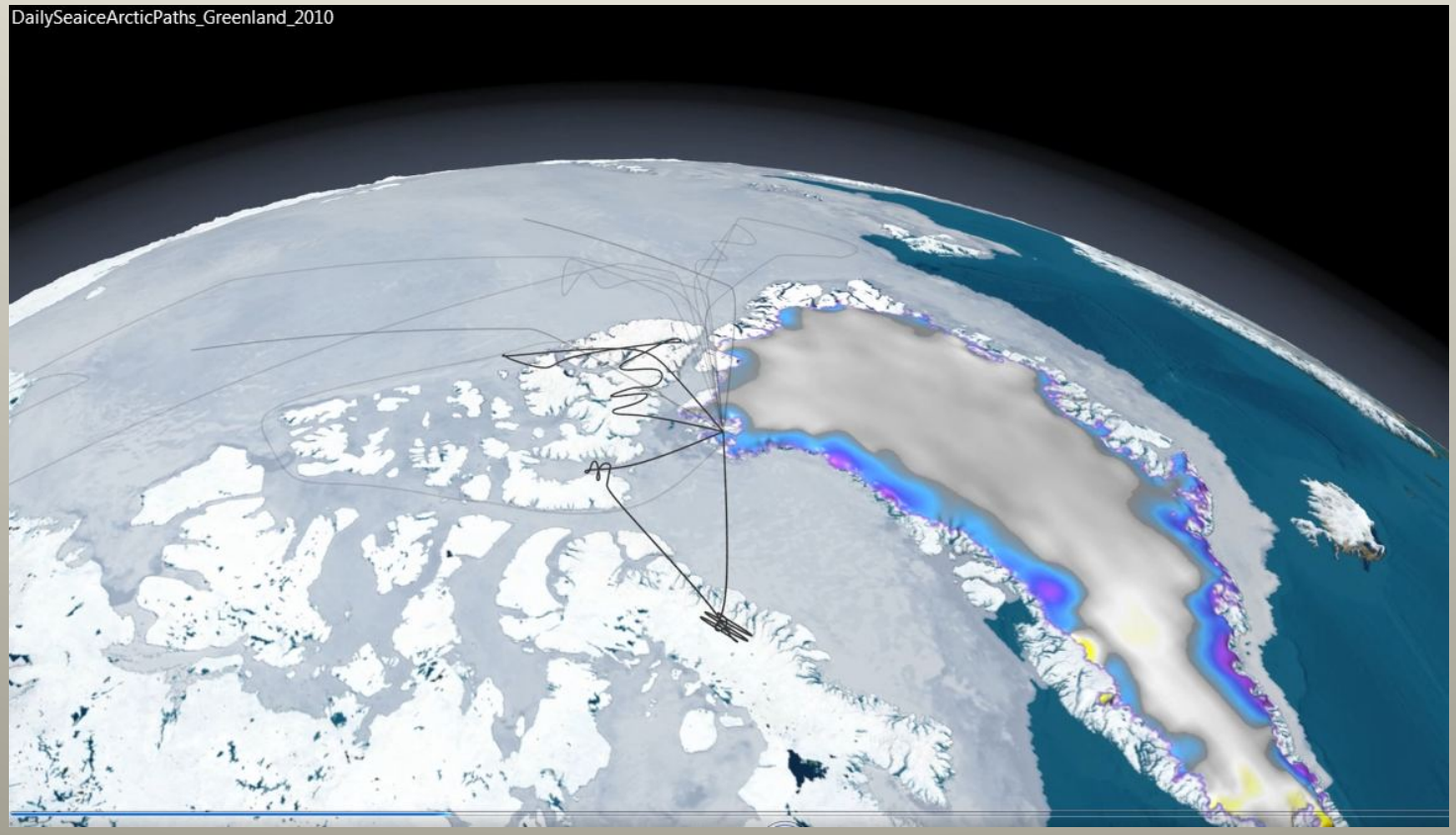
Greenland with no ice

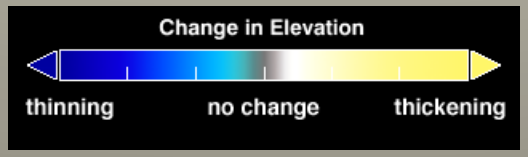


Greenland
Bedrock Topographical Map

Arctic / Greenland

Arctic/Greenland Sea/Land Ice Flights2010

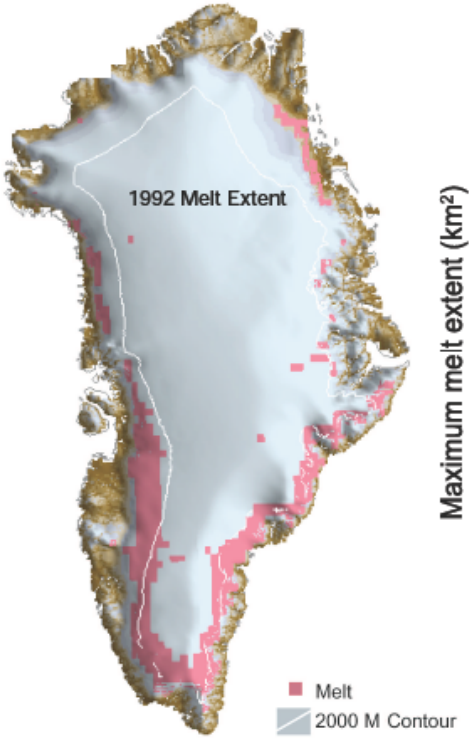


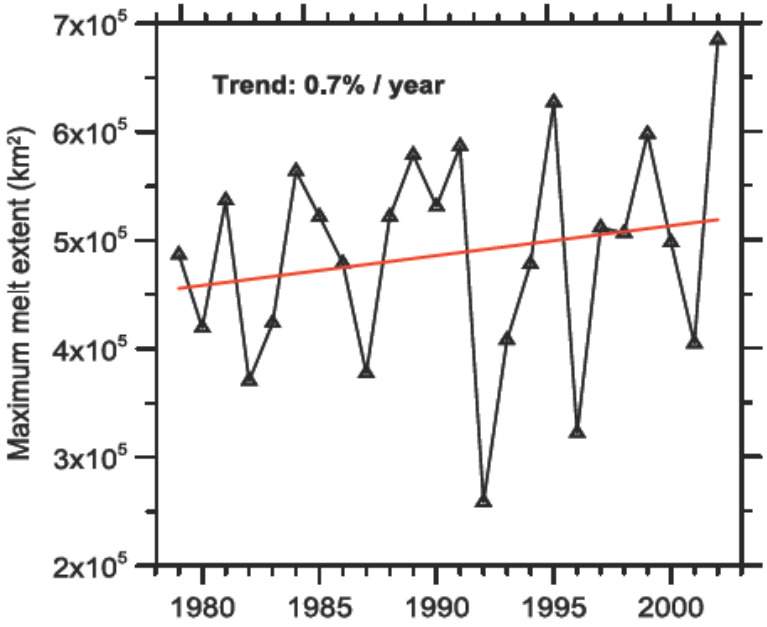


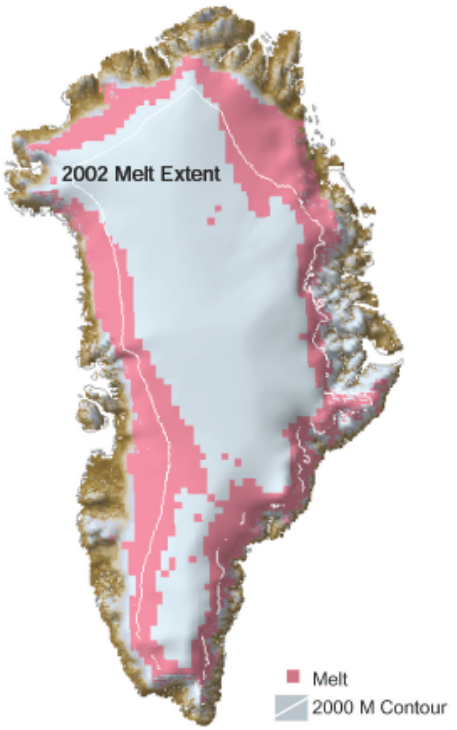
ESPO
NASA

Melting Arctic Ice

Passive Microwave derived maximum melt extent







Greenland ice sheet melt area increased on average by 16% from 1979 to 2002. The smallest melt extent was observed after the Mt. Pinatubo eruption in 1992

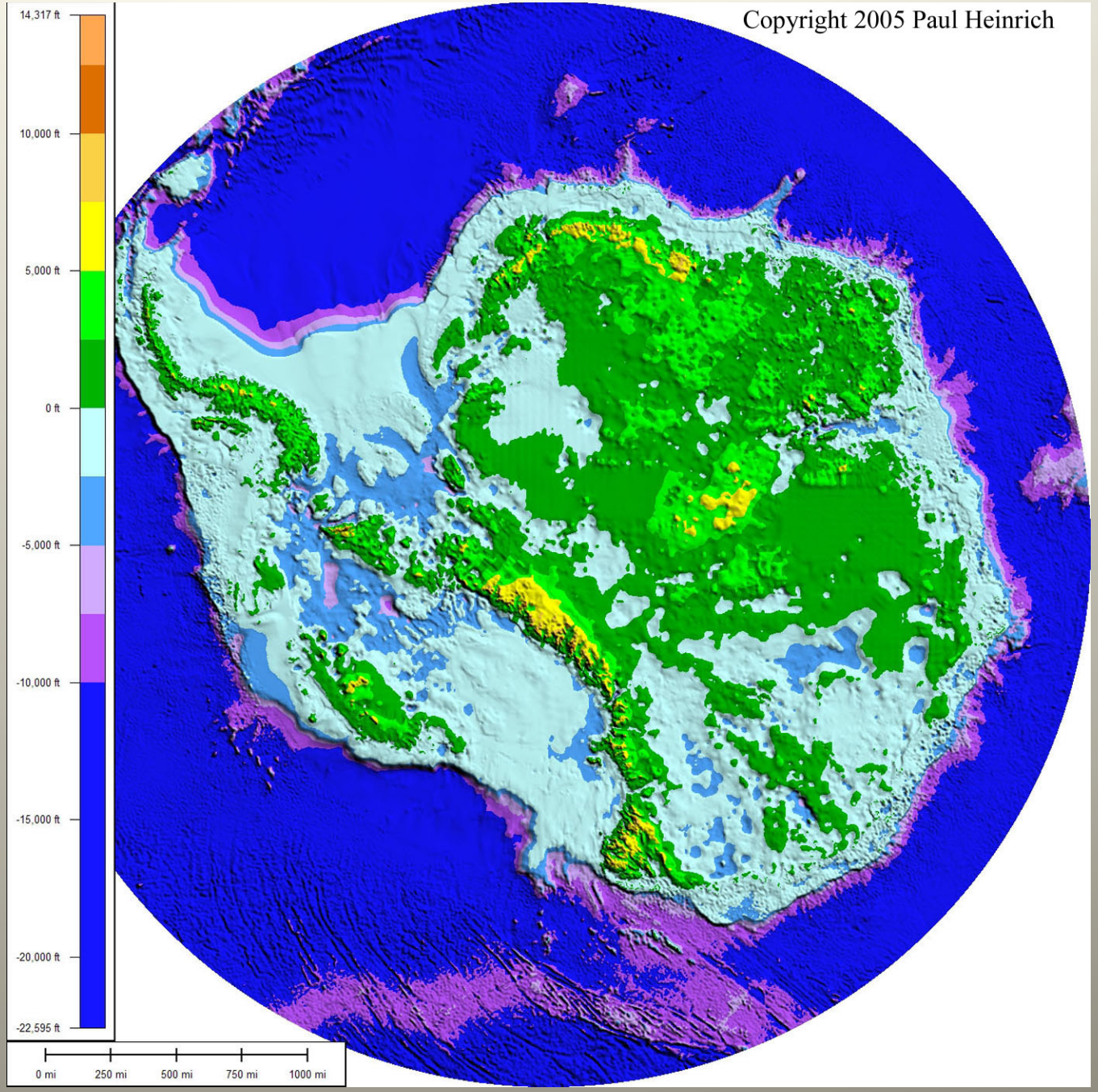
University of Colorado

Konrad Steffen and Russell Huff, University of Colorado at Boulder

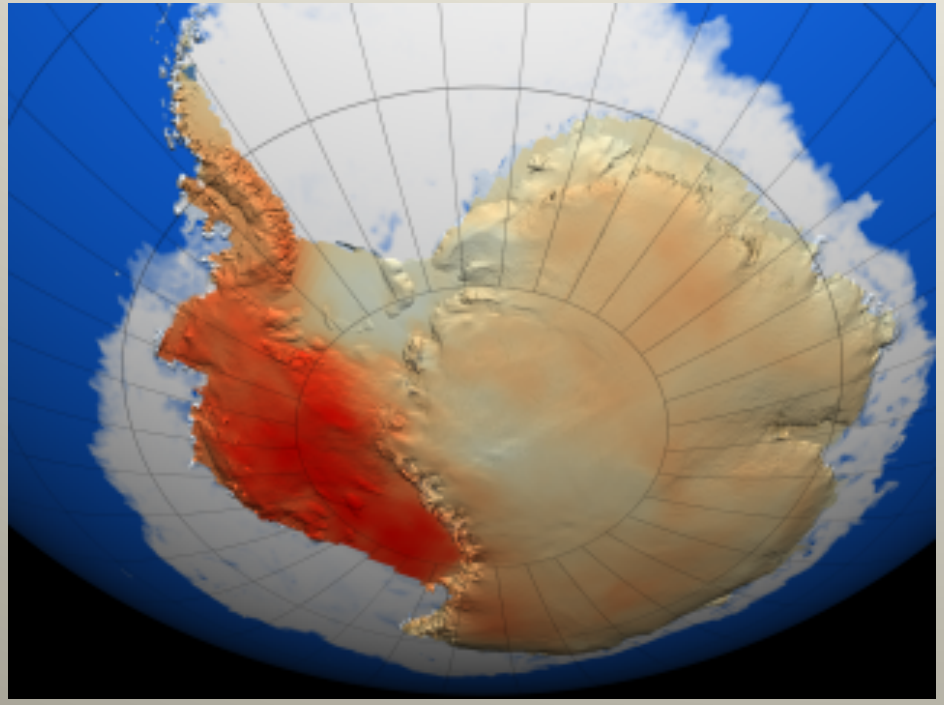
ESPO NASA

Antarctica with no ice

Antarctica
Bedrock Topographical
Map

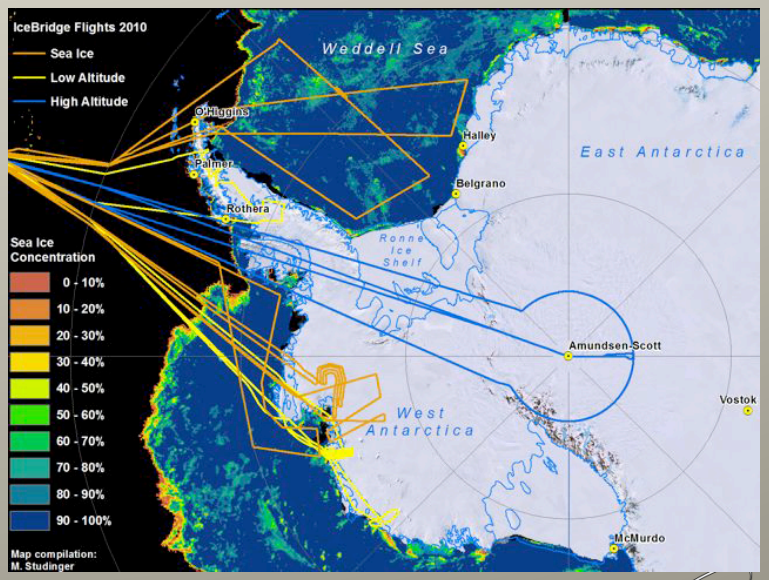


Melting Antarctic Ice



The image incorporates temperature data collected over a 50-year period from 1957 to 2006

Antarctica 2009 Flights



Antarctica 2010 Flights

ESPO NASA

Sea Level Rise

- According to the Third Assessment Report of the International Panel on Climate Change, the ice contained within the Antarctic Ice-sheet represents **61.1 metres** of sea-level change. The ice contained within Greenland Ice Sheet represents a sea-level rise equivalent of **7.2 metres**.

Read more:
http://wiki.answers.com/Q/If_Antarctica_melted_how_much_would_the_sea_level_rise#ixzz1NCO1yzOQ

NASA Antarctica DC-8

The big question

How much do human's contribute to earths changing processes?

How and Why?

“The number of microorganisms in a culture broth will grow exponentially until an essential nutrient is exhausted.”

Metaphorically
Earth = Culture Broth
Microorganisms = Humans

"20,000 species are used in traditional medicine, which forms the basis of primary health care for about 80% of the 3 billion people in developing countries"

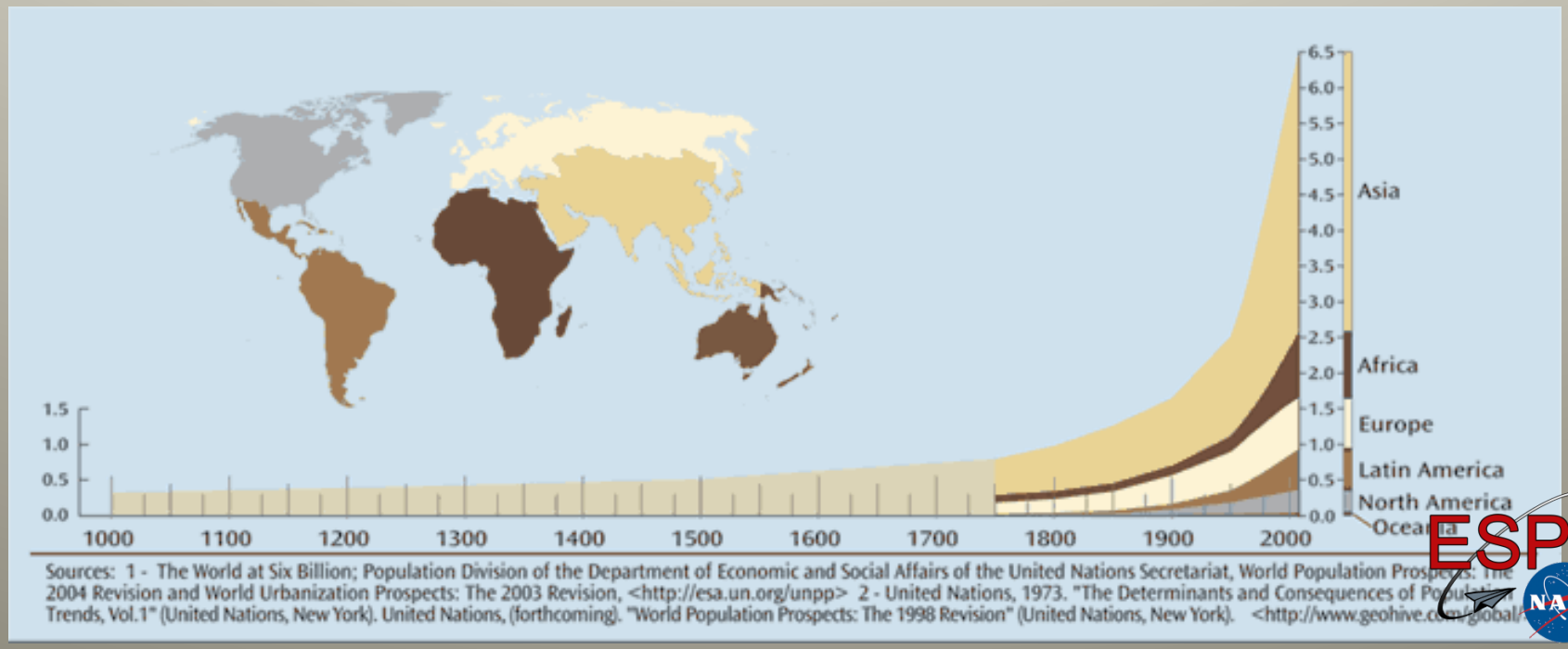
ESPO
NASA

Human Population

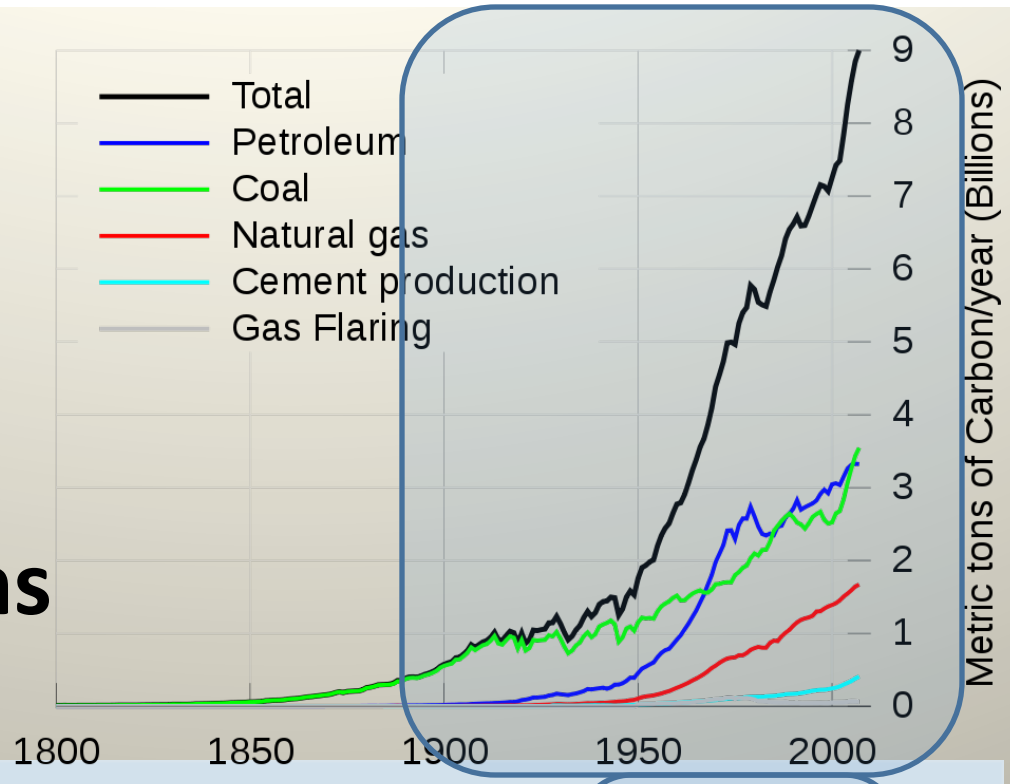
"The collapse of the first civilization on earth, the Summerian, affected only a half a million.
The fall of Rome affected tens of millions. If ours were to fail... it would bring catastrophe on billions." 1

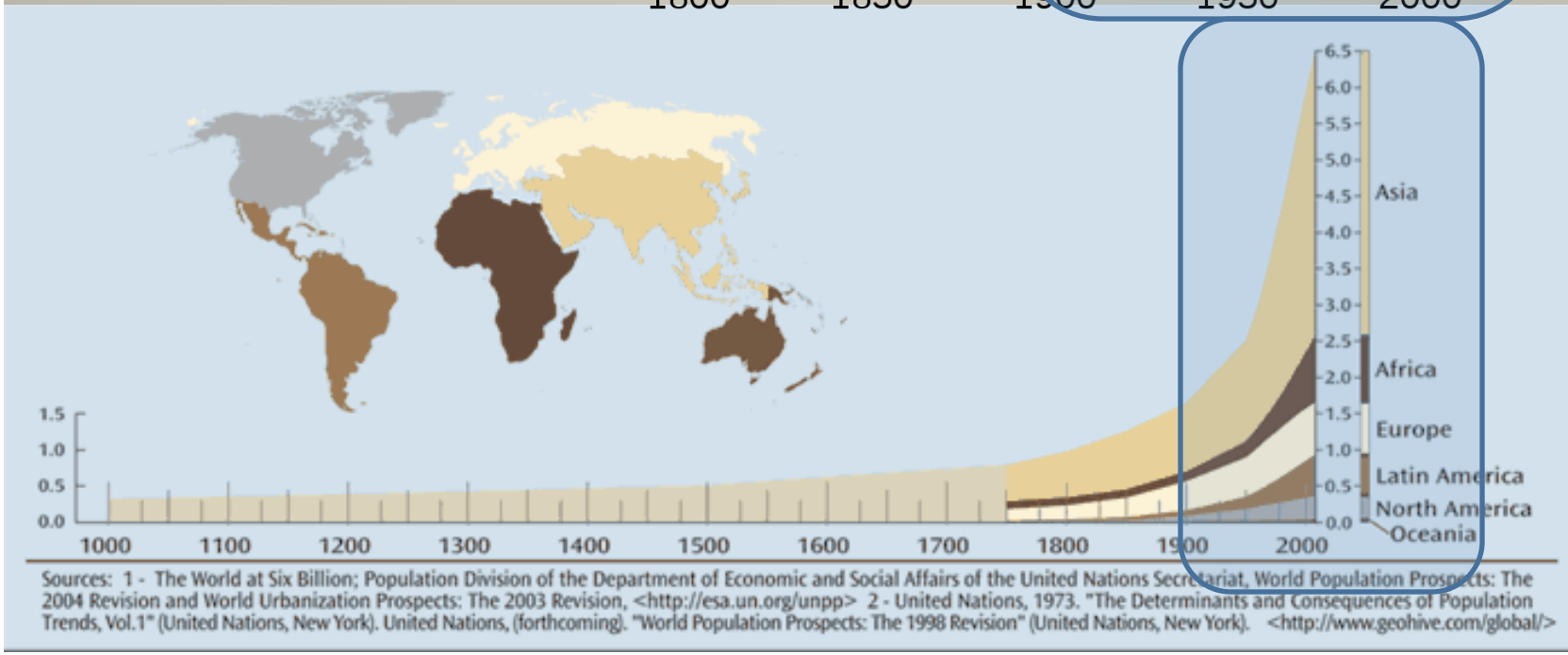
Directly or indirectly, the human species already captures nearly 40% of the total biological productivity on land and 70% of the productivity of the marine environment - the "net primary productivity" of the planet - for its exclusive use. The rate of increase in human use is about 2% per year." 2

The biotic crisis - as a direct result of industrial civilization's disruptive impact, planet earth has begun the 6th great biological extinction period in its entire 4.5 billion year history. During previous extinction events biodiversity was reduced by up to 70-90%. After past events, recovery took roughly 5 million years. However, the current depletion of biological diversity and in particular the prospect of severe depletion if not virtual elimination of tropical forests, wetlands, estuaries and coral reefs that have been the "engines of biodiversity" for hundreds of millions of years, may have profound effects on the evolutionary processes that have previously fostered rediversification. Even our largest protected areas will be far too small for the further speciation of large vertebrates. On the time scale of the human species, environmental disruption (or at least aspects of it) is permanent. 3



Population VS. Carbon emissions

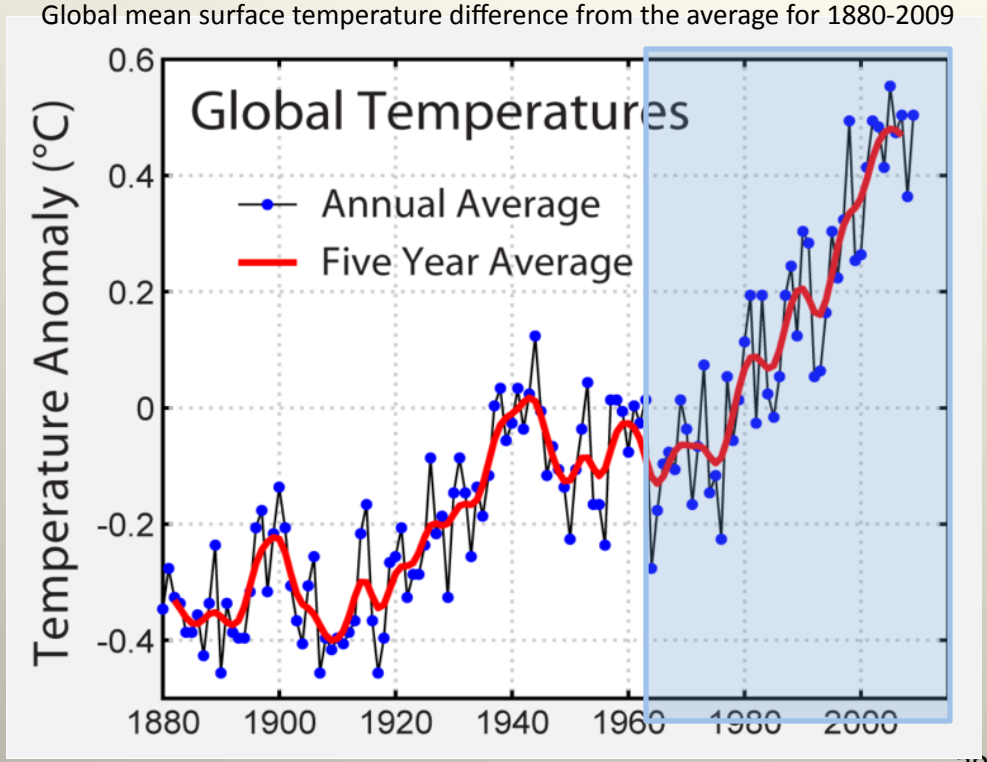




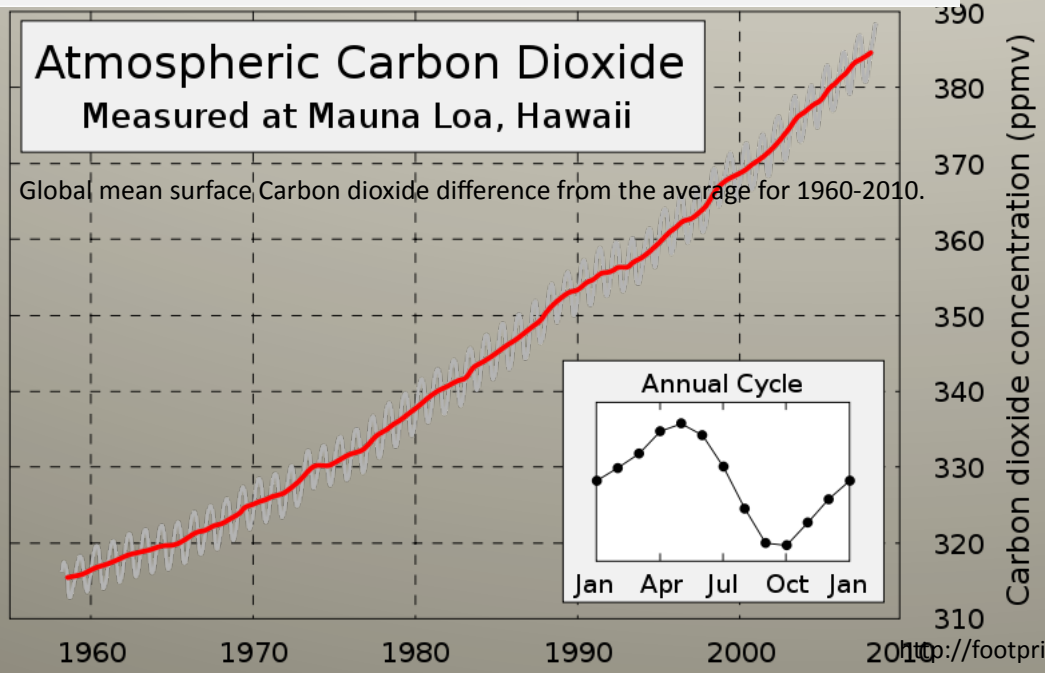
Sources: 1 - The World at Six Billion; Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, <http://esa.un.org/unpp> 2 - United Nations, 1973. "The Determinants and Consequences of Population Trends, Vol.1" (United Nations, New York). United Nations, (forthcoming). "World Population Prospects: The 1998 Revision" (United Nations, New York). <http://www.geohive.com/global/>

ESPO
NASA

Global mean surface temperature difference from the average for 1880-2009



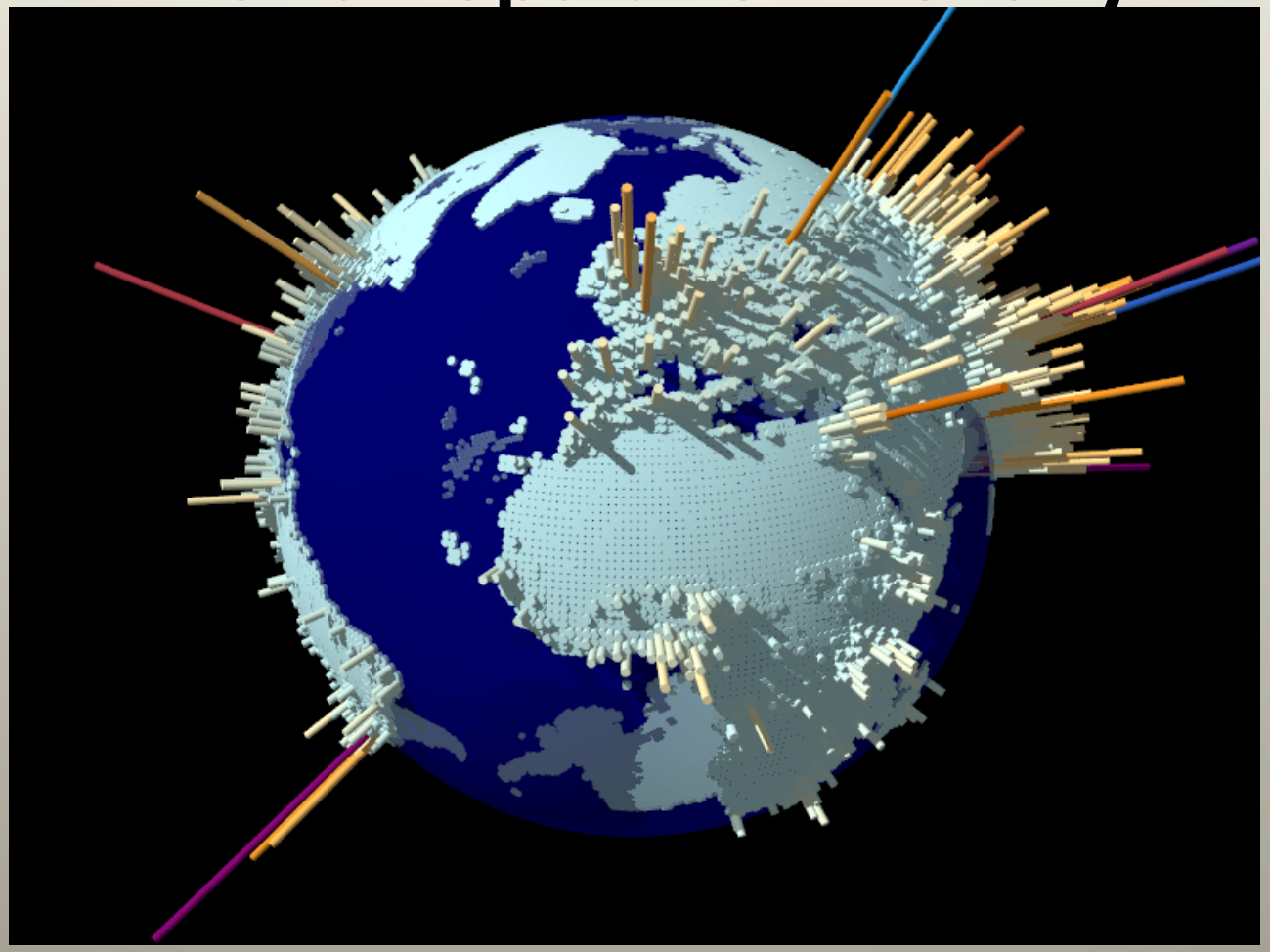
Carbon emissions VS. Global Temperatures



Global mean surface Carbon dioxide difference from the average for 1960-2010.

http://footprintsintheearth.blogspot.com/2010/07/save-earthsave-yourself.html

World Population Density

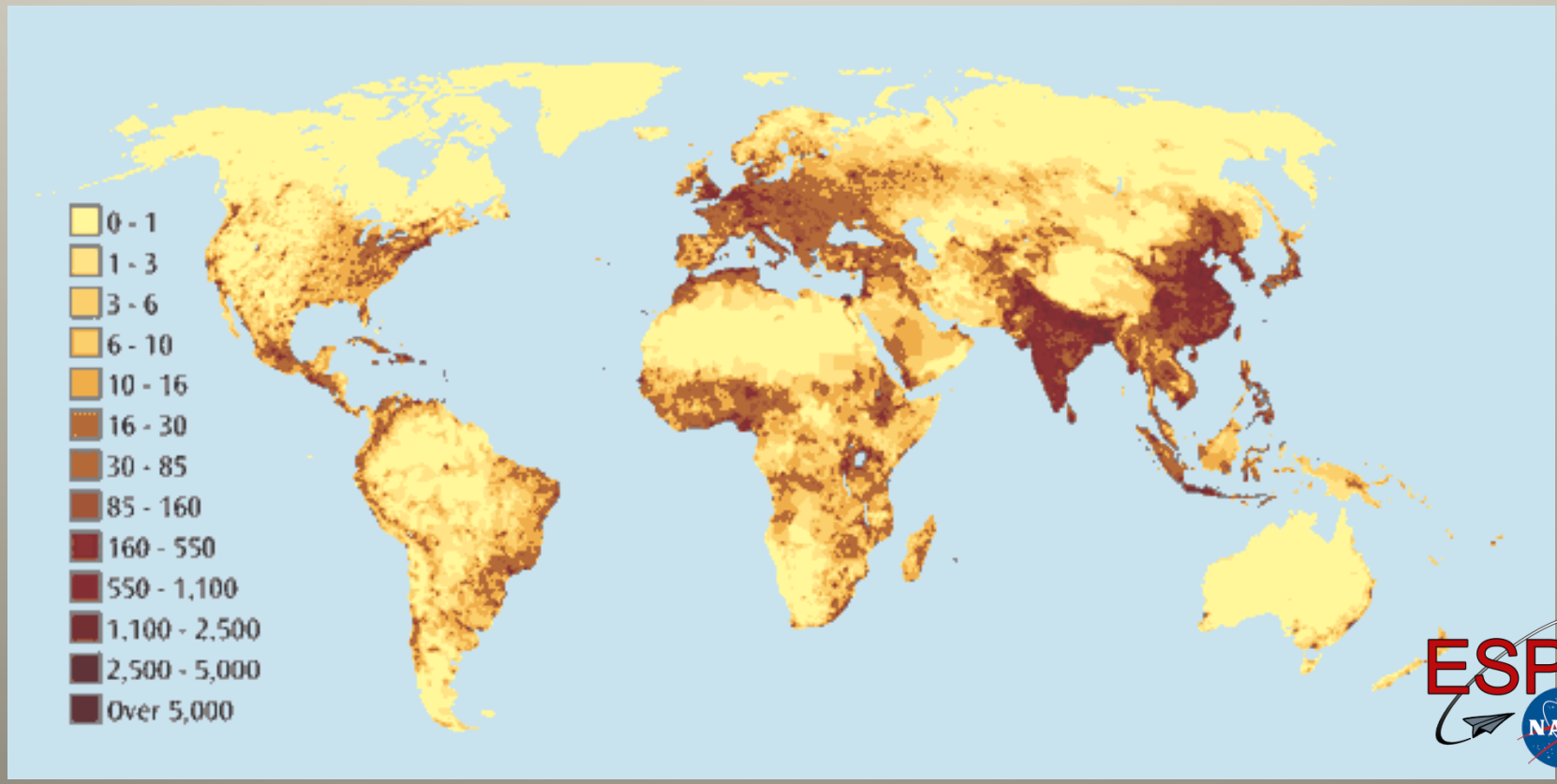


World Population Globe representation
Image by Arenamontanus via Flickr
Population density. Data from the G-Econ project gecon.yale.edu/
Rendered using Matlab and PovRay.

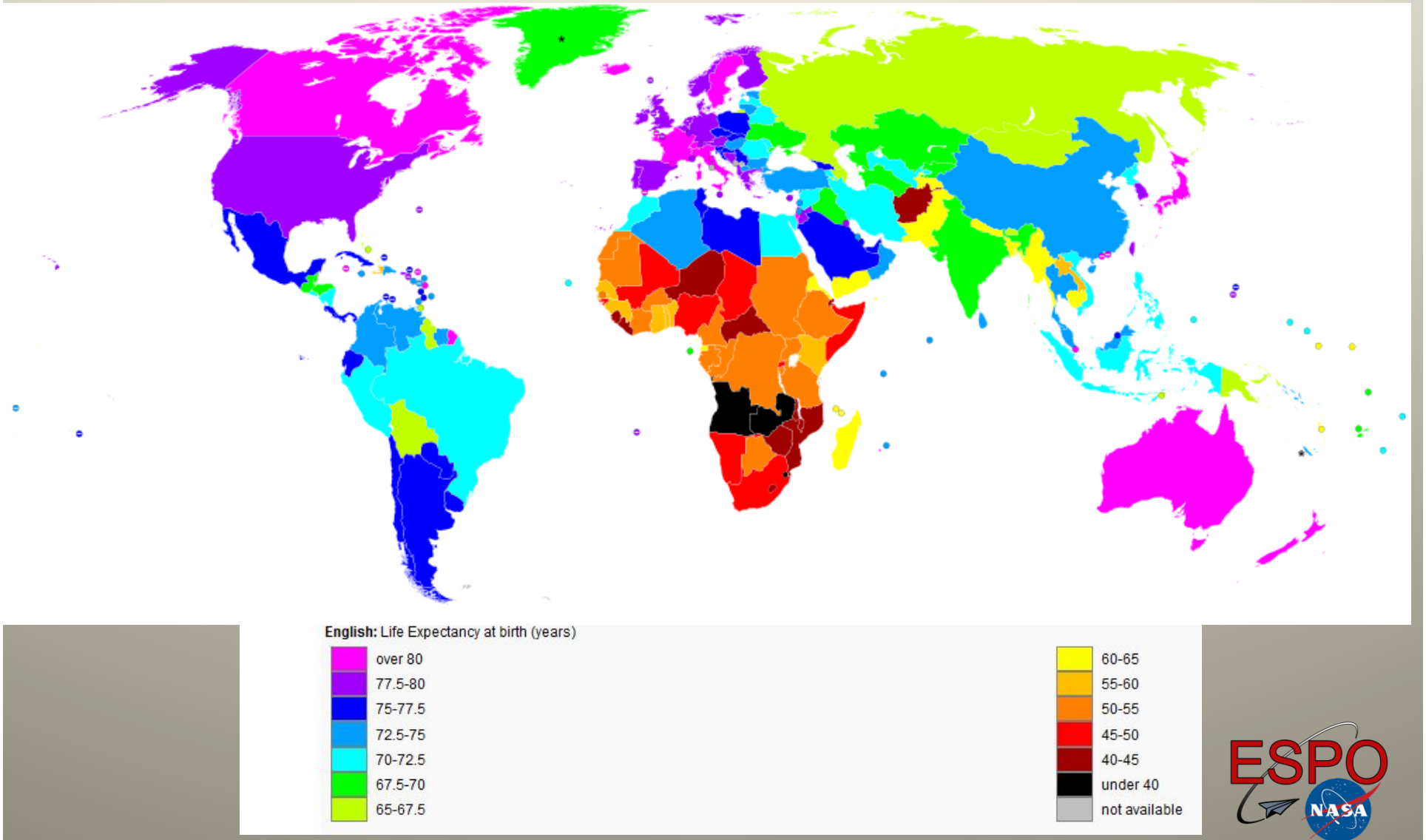
Growth of Urban Areas

The world's rural population has reached its peak and the world's urban slums (with 1 billion people and 32% of the global urban population) will absorb almost all further population growth - likely 1 billion more slum dwellers within 30 years.

"The average size of the world's 100 largest cities grew from around 0.2 million in 1800 to 0.7 million in 1900 to 6.2 million in 2000."



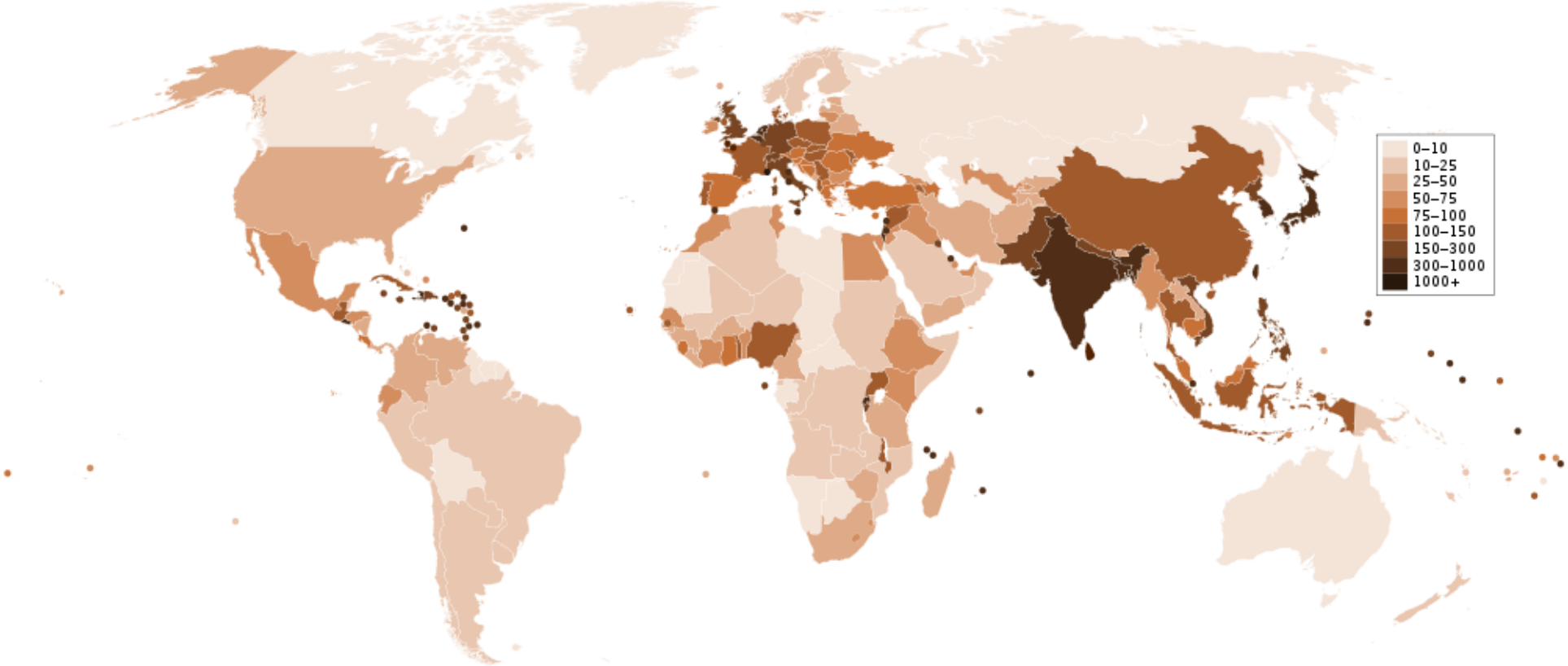
Average Life-Span in years/country



Average Life Span by Era

Humans by Era	Average Lifespan at Birth (years)	Comment
Upper Paleolithic	33	At age 15: 39 (to age 54)[6][7]
Neolithic[8]	20	
Bronze Age and Iron Age[9]	26	
Classical Greece[10]	28	
Classical Rome[10]	28	At age 15: 37 (to age 52)
Pre-Columbian North America[11]	25-30	
Medieval Islamic Caliphate[12]	35+	
Medieval Britain[13][14]	30	At age 21: 38 (to age 59) as an average for British aristocrats[15]
Early Modern Britain[9]	40+	
Early 20th Century[16][17]	30-45	
Current world average[18]	67.2	2010 est.

Population Density by Country



ESPO
NASA

#1 Reason for Global Climate Change

Dhaka Bangladesh

To many people!!

ESPO NASA

Earths Optimal Population??

- **Estimations**
- Various end-targets are often balanced together in estimating the optimum human population, and different emphasis on different end-targets cause variability among estimates.
- The optimal world population has been estimated by a team co-authored by Paul R. Ehrlich.[4] End-targets in this estimation included:
- Decent wealth and resources to everyone
- Basic human rights to everyone
- Preservation of cultural diversity
- Allowance of intellectual, artistic, and technological creativity
- Preservation of biodiversity
- **Based on this, the estimation of optimum population was to be roughly around 1.5 billion to 2 billion people.[4]**
- The UK based think tank Population Matters, (formerly known as the Optimum Population Trust), has calculated the optimum population of nearly 150 countries.[5]

Direct Human Effect on Earth

- Population – the more people the more issues affecting the globe
- MORE Manufacturing and Consumption
- MORE Atmospheric pollution
- MORE Water Pollution
- MORE Soil Degradation

More of everything!!

Earth's Changing from Anthropogenic (human) Influences

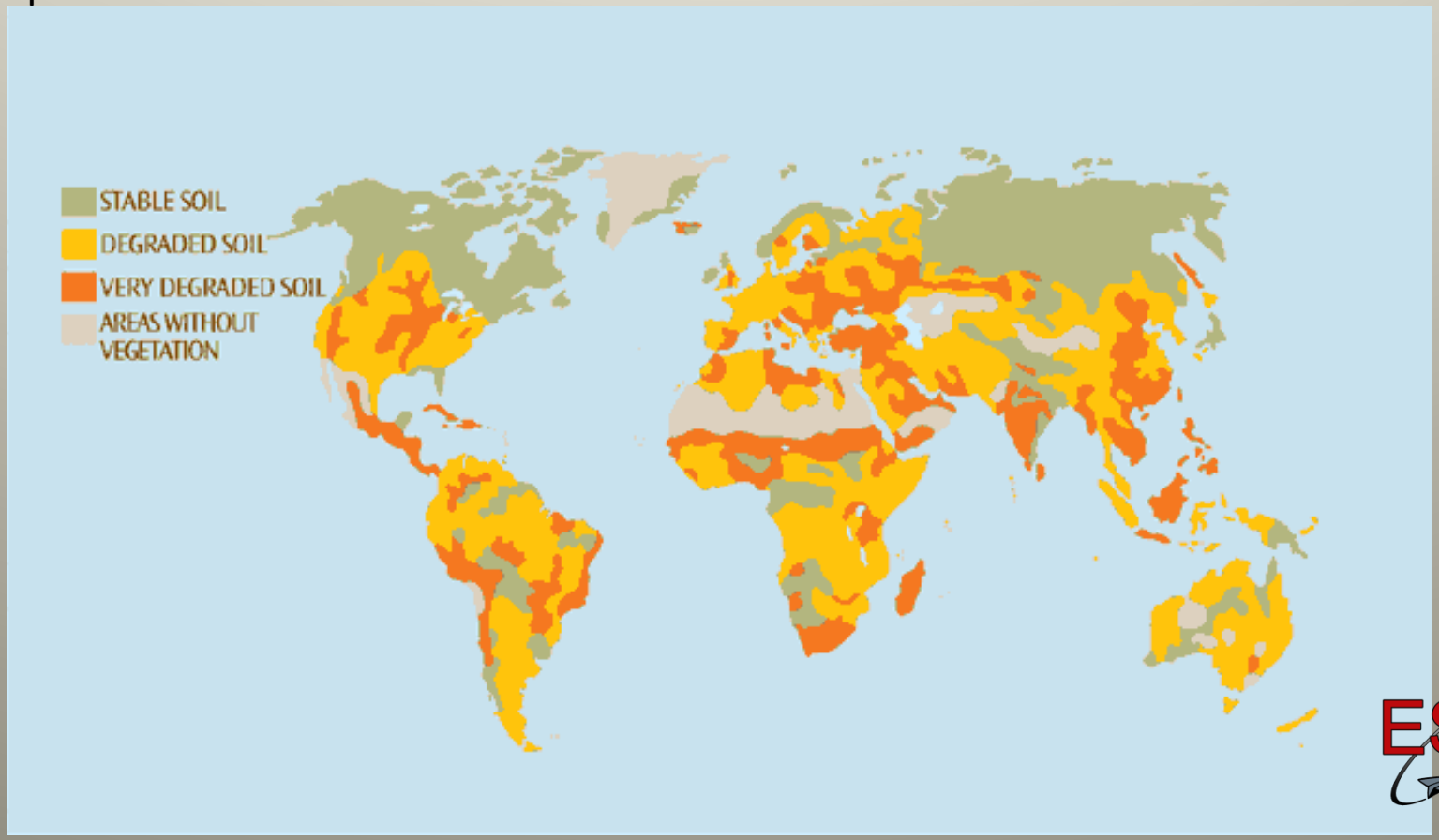
- Solar Radiation increasing due to increased CO2, methane and other pollutants- decreased reflectance
- Atmospheric Temperatures increasing
- Ocean temperatures increasing
- Rising Sea Levels –due to temperature increases
- Mass migration away from current coastline
- Immigration issues between countries
- Farming - food shortages
- Wildlife/insect/plant extinction
- Massive Economic Changes
- Global Power Struggle

ESPO NASA

Human Influence on Soil Degradation

About 2 billion hectares of soil, equivalent to 15 per cent of the Earth's land area (an area larger than the United States and Mexico combined), have been degraded through human activities.

"Over the past 40 years, approximately 30% of the world's cropland has become unproductive."



ESPO NASA

Human Population and Coastal Waters

Things that can help but what is the tipping point ? Can we turn the clock back?

- ***Global leadership is Required***
- Lower emissions from every person
- Different manufacturing policies and procedures world wide
- Personal ownership of the problem
- Continued research for understanding

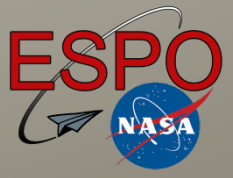
.....Maybe

But we have to do our best to be good Stuarts to this planet

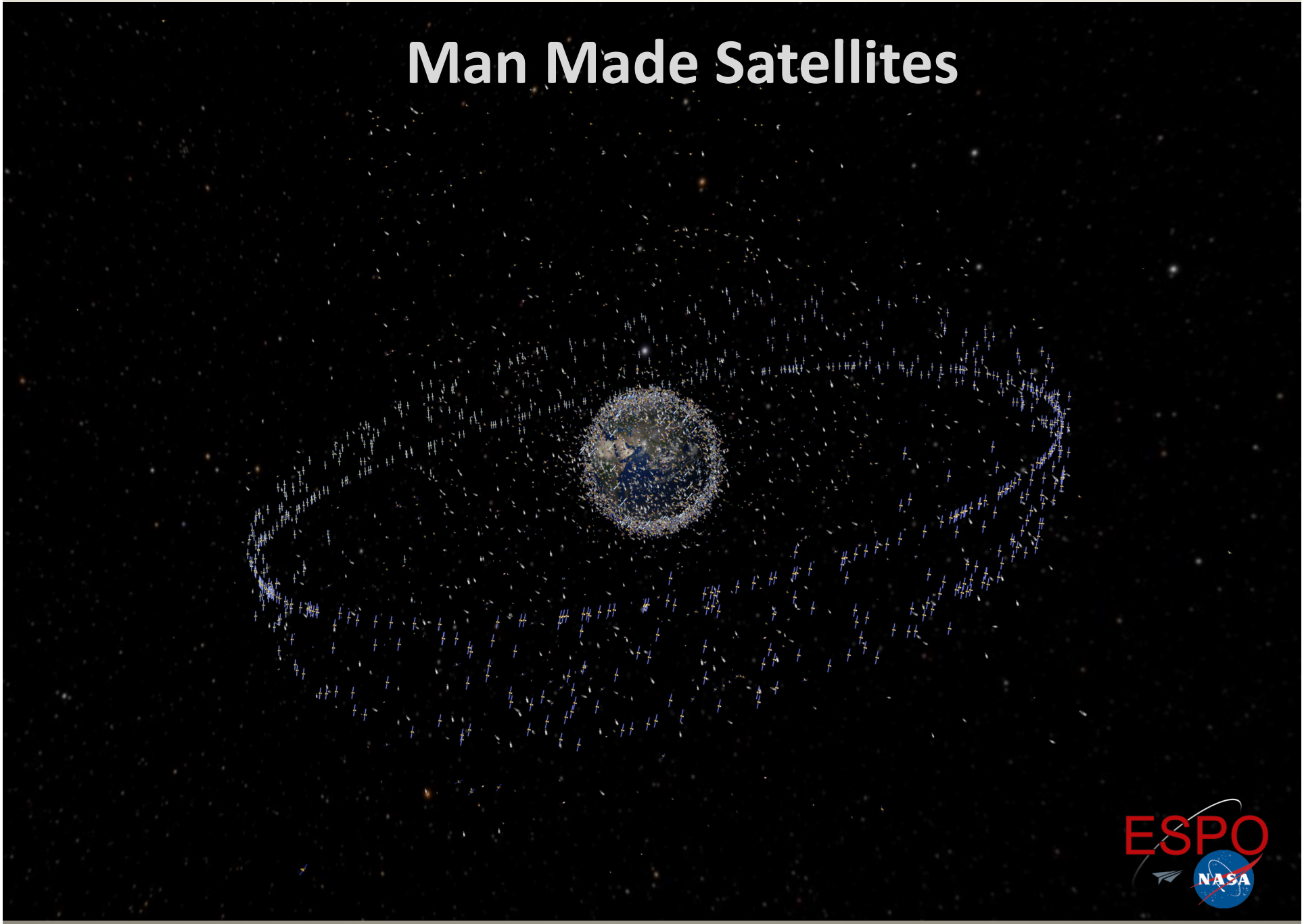
ESPO NASA

Earth Science Research + World Economics = Double Edge Sword

- Wealthy countries pay for research
  - CON - Wealthy countries expect massive consumption to continue (Capitalism)
- Poorer countries need economic assistance
  - Wealthy countries utilize poor countries for production of goods (cheap labor = cheap products)
  - Economically dependent on the Wealthy countries massive consumption



Man Made Satellites



Baffin Island Canada -
North America's last remaining Ice Cap

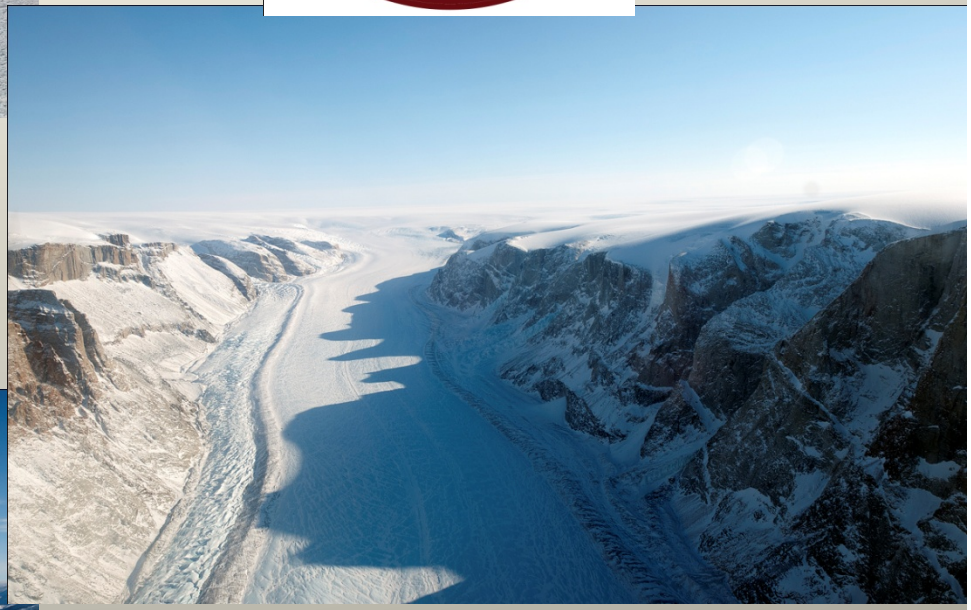
Northern Greenland Glacier

Pitufik Glacier

All glacier images take by Michael Studinger.
Operation IceBridge Project Scientist

ESPO

Umimamako Glacier



South Eastern Glacier

Petermann Glacier – new calving

All glacier images take by Michael Studinger.
Operation IceBridge Project Scientist

Resourses

Human Population:
Text Sources:
1. A Short History of Progress, Ronald Wright, House of Anansi, 2004
2. Environmental Research Foundation, www.ejnet.org/rachel/rhwn256.htm
3. The Biotic Crisis and the Future of Evolution, PNAS - www.pnas.org/cgi/content/full/98/10/5389

World Population Density Map Source:
Center for International Earth Science Information Network, Columbia University, "Grided Population of the World"
Text: 1. The Challenge of Slums - UN-HABITAT's Global Report on Human Settlements, www.unchs.org

2. UN World Water Development, www.unesco.org/water/wwap/facts_figures/water_industry.shtml

Biodiversity:
http://news-service.stanford.edu/news/1997/october29/population.html; What We Must Do to Counter the Biotic Holocaust, Myers, www.nwf.org/internationalwildlife/1998/holocaus.html

ESPO
NASA

Resourses

Life span world map
http://en.wikipedia.org/wiki/File:Life_Expectancy_2008_Estimates_CIA_World_Factbook.svg

Exponential Growth
http://en.wikipedia.org/wiki/Exponential_growth

Optimal Population
Gretchen C. Daily, Anne H. Ehrlich, and Paul R. Ehrlich. *Optimum Human Population Size*.
Population and Environment: A Journal of Interdisciplinary Studies Volume 15, Number 6, July 1994 01994 Human Sciences Press, Inc.
^ Optimum Population Trust: "Sustainable populations by country"

Soil Degradation Map Source:
UN GLASOD: 1990 Global Assessment of Human Induced Soil Degradation,
http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/GLASOD.htm
Text:
1. UN Global Environment Outlook
3, www.grida.no/geo/geo3/english/141.htm
2. "Soil as an Endangered Ecosystem", David Pimental, Bioscience; Nov 2000

Climate REEL
NASA videos for climate change
http://climate.nasa.gov/ClimateReel/

http://downloads.globalchange.gov/ocp/ocp2011/ocp2011.pdf

ESPO NASA